Release of the New National Solar Radiation Database (NSRDB)

NSRDB Webinar

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December 08, 2015

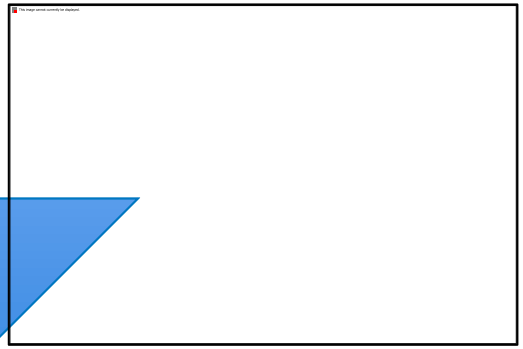
Webinar Outline

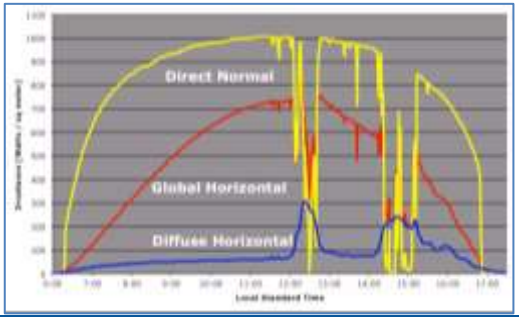
- **Motivation and History**
- **Development of the New Gridded NSRDB**
  - Physical Solar Model (PSM) Framework
- **New NSRDB Website and How to Access Data**
- **Data Availability**
- **Future Plans**

Motivation

Support DOE SunShot goal of reducing the costs of solar deployment and financing through providing high-quality publicly available solar resource information

Concept	Policy Decisions Site / Technology Selection
Feasibility	Investor Commitment Project Approvals
Due Diligence	Engineering Design System Integration
Operations	System Tests Operation & Maintenance Energy System Integration





National Solar Radiation Database: History

http://nsrdb.nrel.gov

Evolution of Public Solar Data

1952-1975 SOLMET[1] [ERDA, NOAA, 1979]

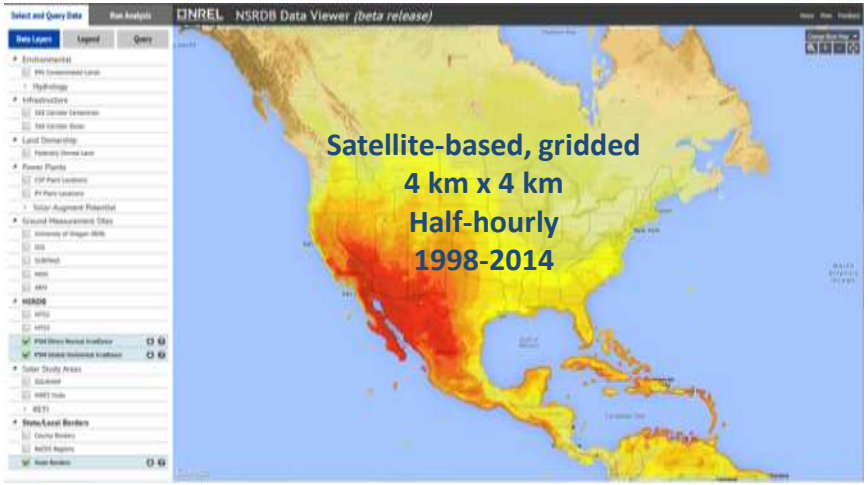
1961-1990 NSRDB[2] [DOE, NOAA, 1994]

1991-2005 NSRDB-II[3] [DOE, NOAA, 2007]

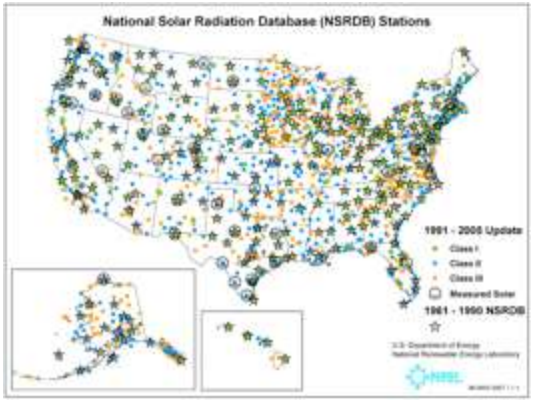
1998-2014 NSRDB [DOE, NOAA, UW, SCS 2015]

(1)
248 stations
with 26
Measurement
Stations
1977-80

(2)
239 ***Modeled***
Stations with
56 partial
measurement
stations
1990



(3)
1,454
Modeled
Locations
1991-2005



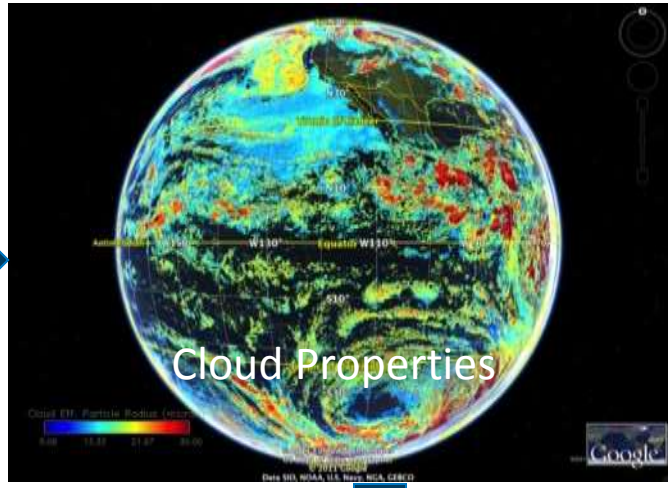
How Do Satellites Model Surface Radiation?

- **Empirical Approach (Traditional Approach):**
  - Build model relating satellite measurements and ground observations (cloud index and clearness index)
  - Use those models to obtain solar radiation at the surface from satellite measurements

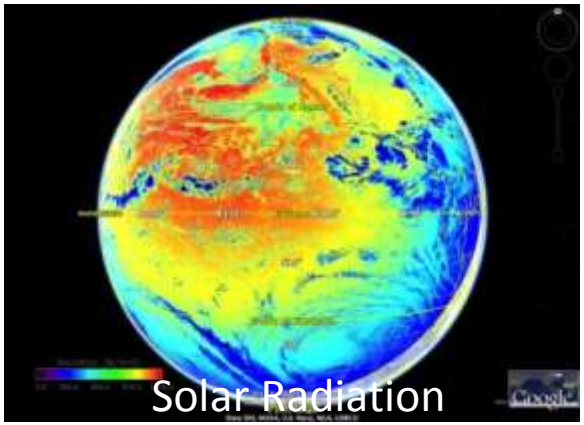
- **Physical Approach: (New Approach)**
  - Retrieve cloud and aerosol information from satellites
  - Use the information in a radiative transfer model

Physical Approach to Satellite Modeling

Satellite-Based Cloud Retrieval Model



Radiative Transfer Models



Physical Solar Model (PSM) Framework

Satellite Input

GOES data—
4 channels:
4 km–30 min

Ancillary Input

NWP Forecast or Reanalysis
Snow
Surface emissivity
Surface reflectance

RT Model Input

Aerosol product from MODIS/MISR satellite and AERONET ground measurements

Retrieval System

PATMOS-x: Cloud algorithms

Radiative Transfer

Clear sky: REST2
Cloudy sky: NREL FARMS model and DISC model

Cloud Products

Cloud mask
Cloud type
Cloud height/temperature/ pressure
Cloud optical depth
Cloud particle size
Cloud water path

Irradiance Products

Global horizontal irradiance (GHI)
Direct normal irradiance (DNI)
Diffuse horizontal irradiance (DHI)

PSM: Ancillary/Met Data

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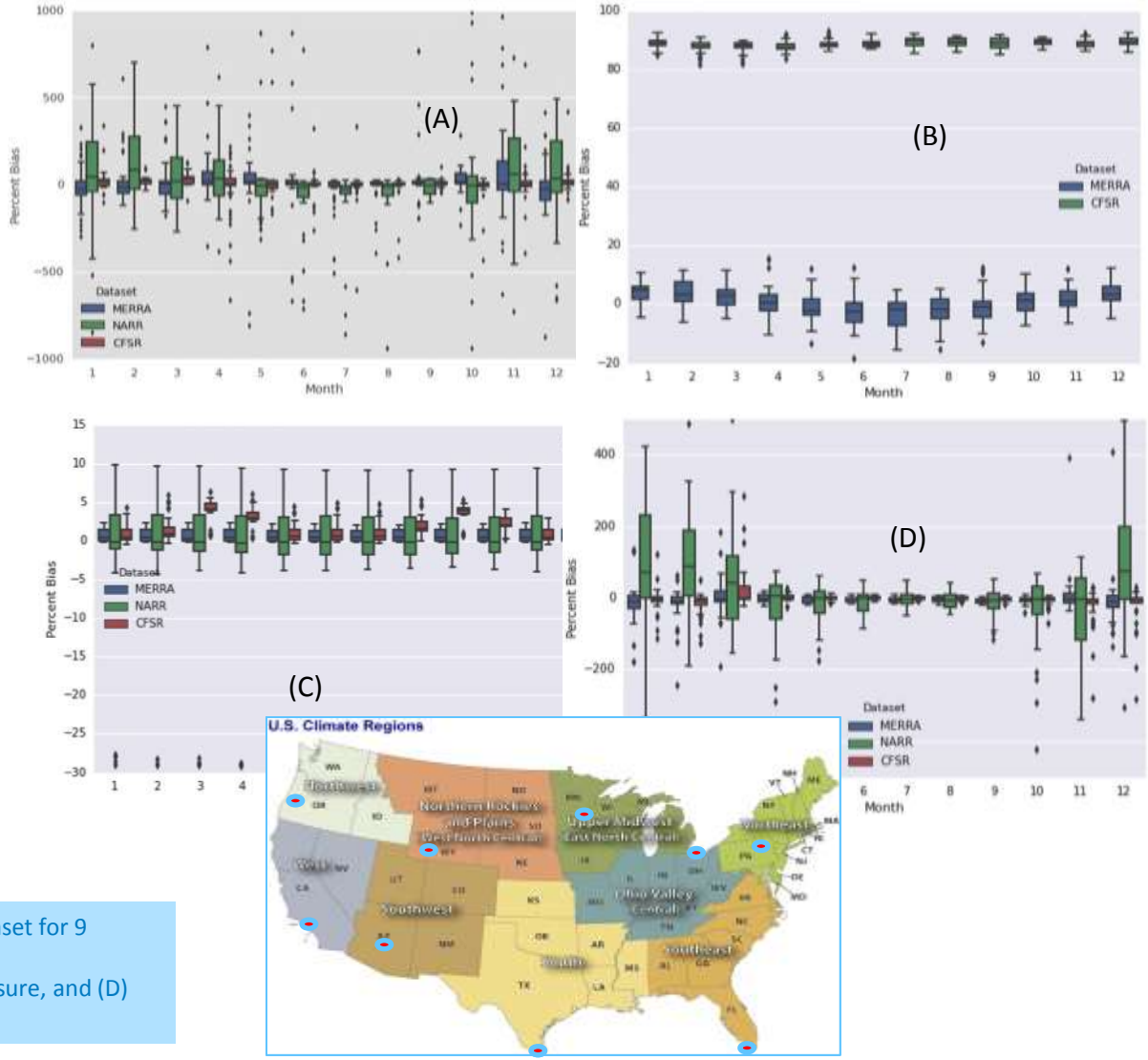
Met Data for PSM

- **Accurate meteorological dataset for use in the NSRDB**

- Various reanalysis datasets compared with ground measurements (all Integrated Surface Database (ISD) stations) to identify best data
- NASA Modern Era-Retrospective Analysis (MERRA) dataset, NOAA's North American Regional Reanalysis (NARR) dataset, and NOAA's Climate Forecast System Reanalysis (CFSR) compared
- MERRA found to be the most accurate



Comparison between ISD and MERRA, CFSR, and NARR dataset for 9 stations
(A) Dew Point, (B) Precipitable Water, (C) Atmospheric Pressure, and (D) Wind Speed comparison

PSM: Cloud Products

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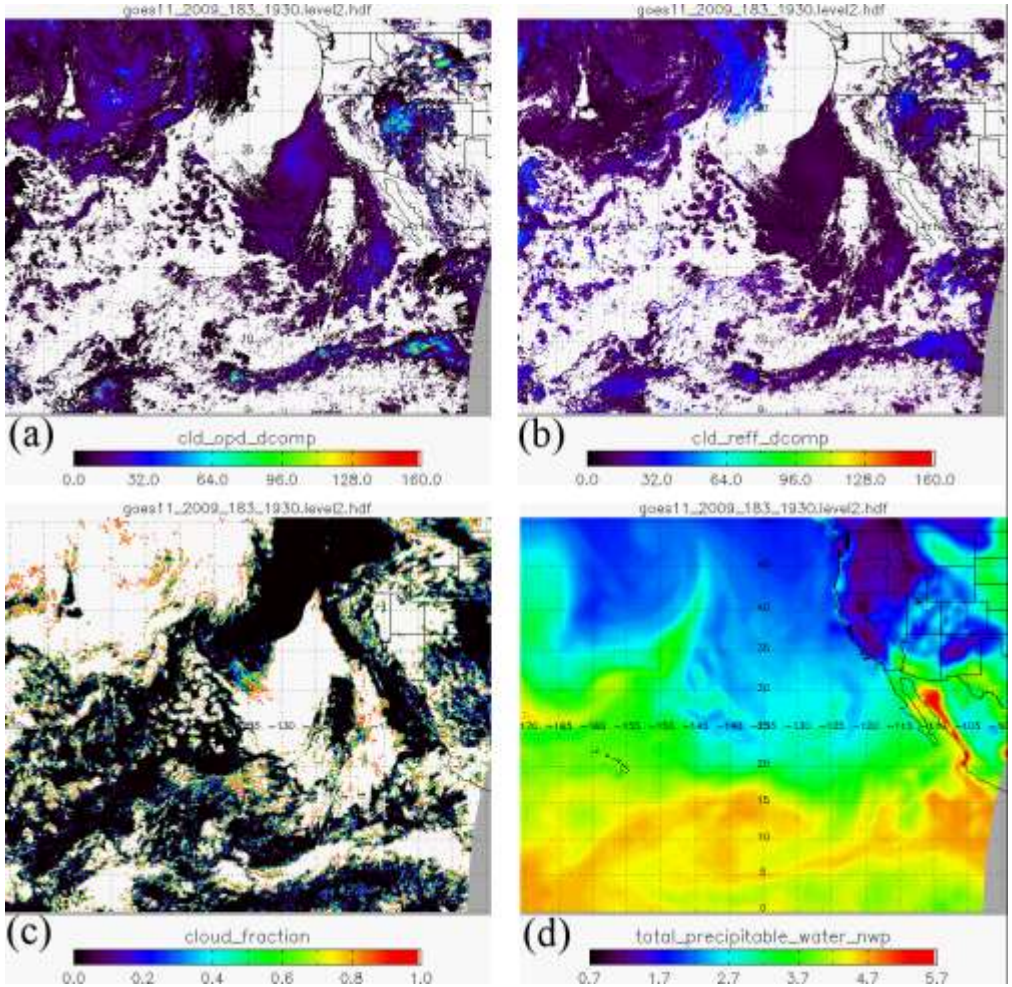
Cloud Products for PSM

- In collaboration with the University of Wisconsin, NREL developed an improved version of the PATMOS-x processing system, which was used to process GOES-WEST and -EAST data for years 1998-2014
- Cloud properties:
  - Cloud mask
  - Cloud type
  - Cloud height/temperature/ pressure
  - Cloud optical depth
  - Cloud particle size
  - Cloud water path



PSM: Aerosols

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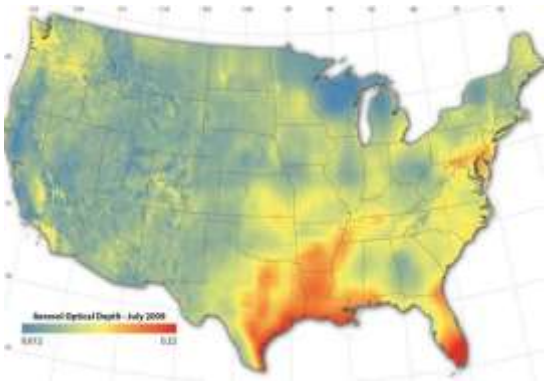
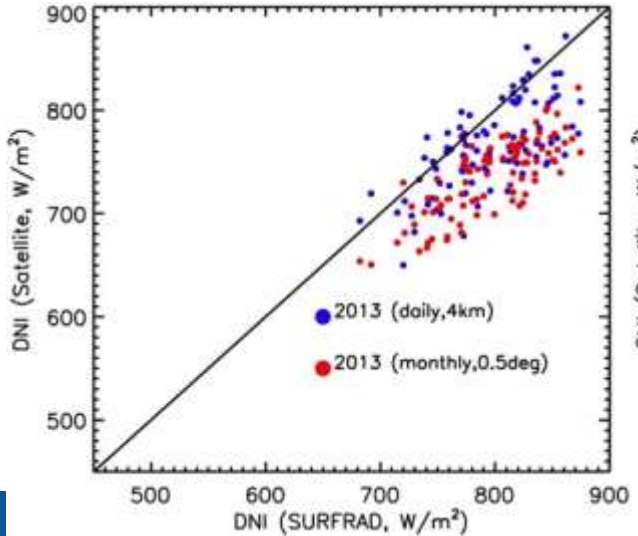
Aerosols for PSM

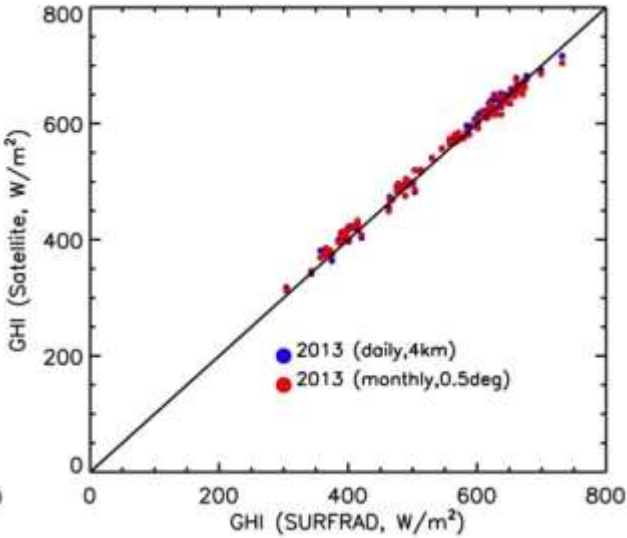
- **Developed accurate gridded aerosol product using multiple data sources**

- Developed monthly 0.5º aerosol optical depth (AOD) for 1998-2014 using satellite and ground-based measurements
- Monthly results interpolated to form daily 4-km AOD data
- Daily data calibrated using ground measurements to develop accurate AOD product

	AOD	MAE(W/m^2)	MAE(%)	RMSE(W/m^2)
Desert Rock, NV	Monthly	17	1.84	20
	Daily	12	1.34	16
Goodwin Creek, MS	Monthly	47	5.96	53
	Daily	30	3.76	36
Bondville, IL	Monthly	62	7.76	67
	Daily	37	4.65	48
Table Mtn., Co	Monthly	35	3.84	41
	Daily	24	2.57	30







PSM: Radiative Transfer Models

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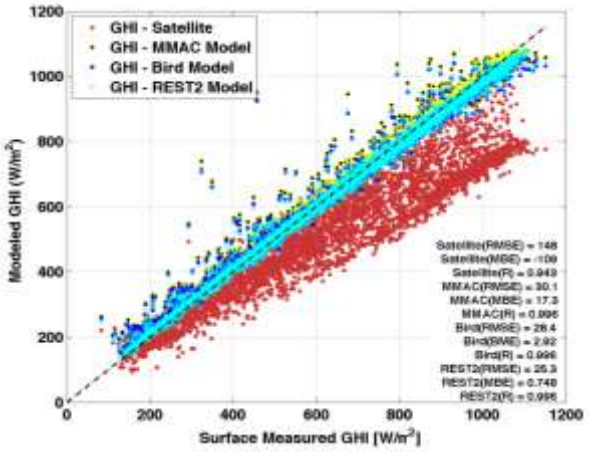
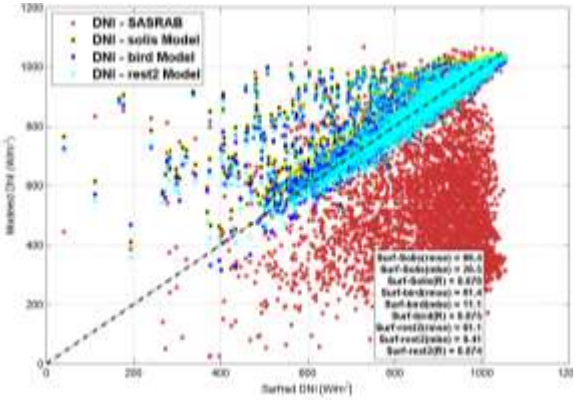
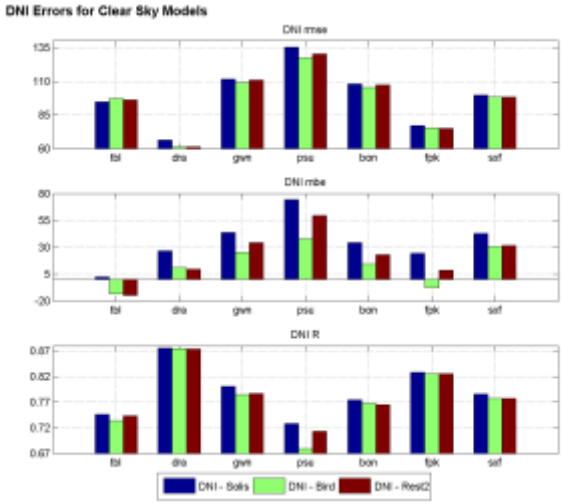
Clear Sky Radiative Transfer Model for PSM

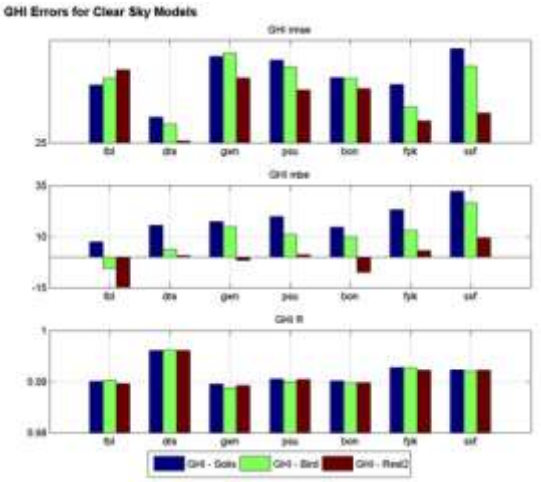
REST2 Clear Sky Model Output with Better AOD Input

- SASRAB model initially tested but provided biased results
- 3 next-generation models (Bird, MMAC, and REST2 models) tested with high-quality aerosol data
- All models provided significantly accurate results
- REST2 provides the most accurate results and was implemented in the PSM framework





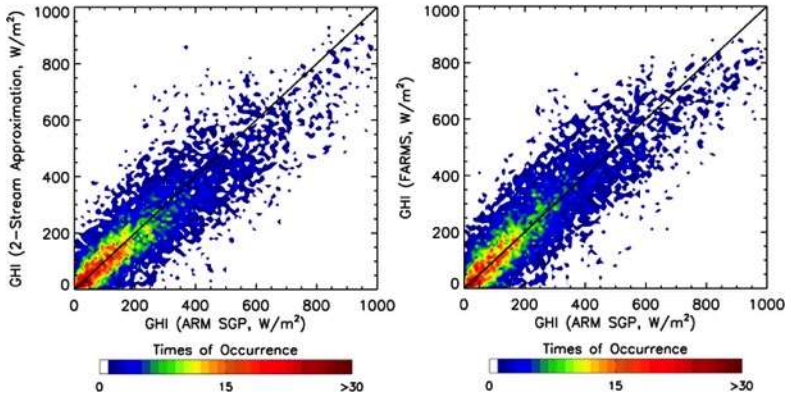




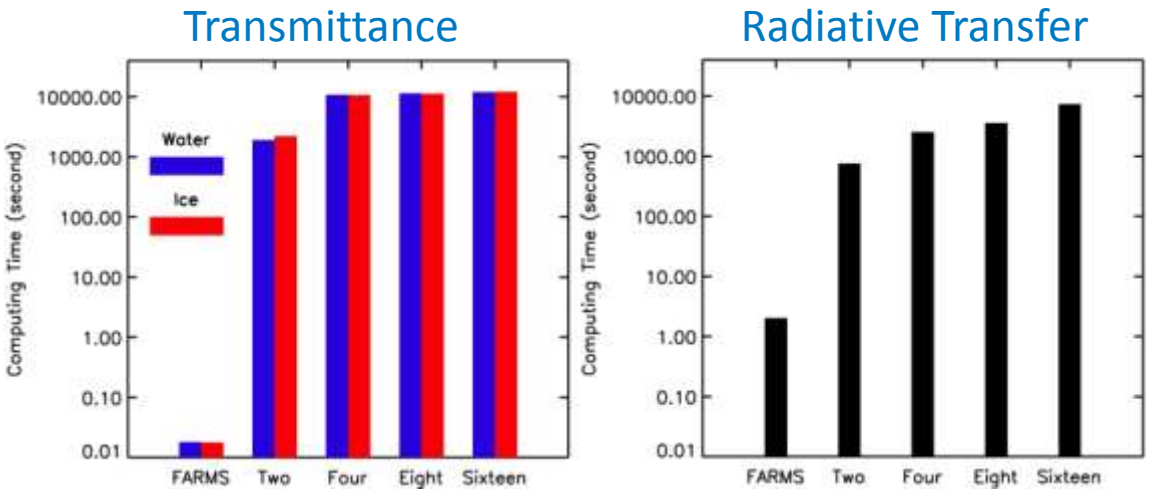
All-Sky Radiative Transfer Model for PSM

- **Fast All-Sky Radiation Model for Solar applications (FARMS)**

  - Developed new radiative transfer model for use in satellite and forecasting applications
  - 2-stream approximation (industry standard) and FARMS have similar performance
  - FARMS is 1,000 times more efficient in the computation of solar radiation

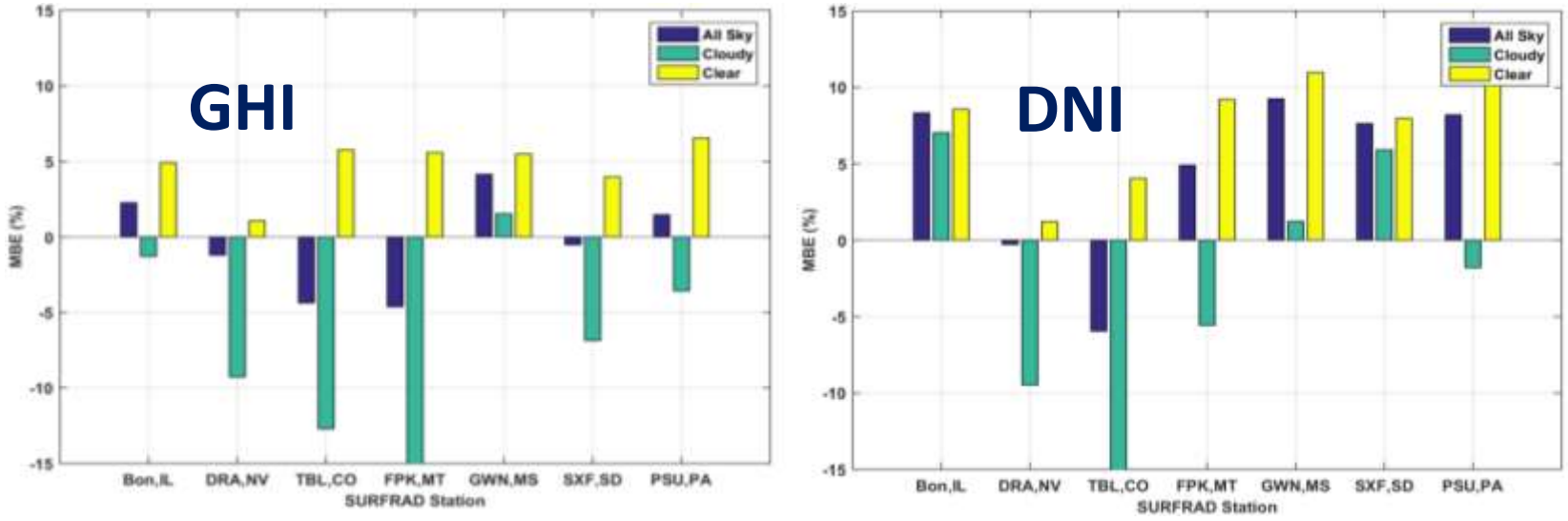


	SASRAB	FARMS
MBE%	5.9	0.4
MAE%	29.9	27.6
MBE (W/m^2)	16.5	1



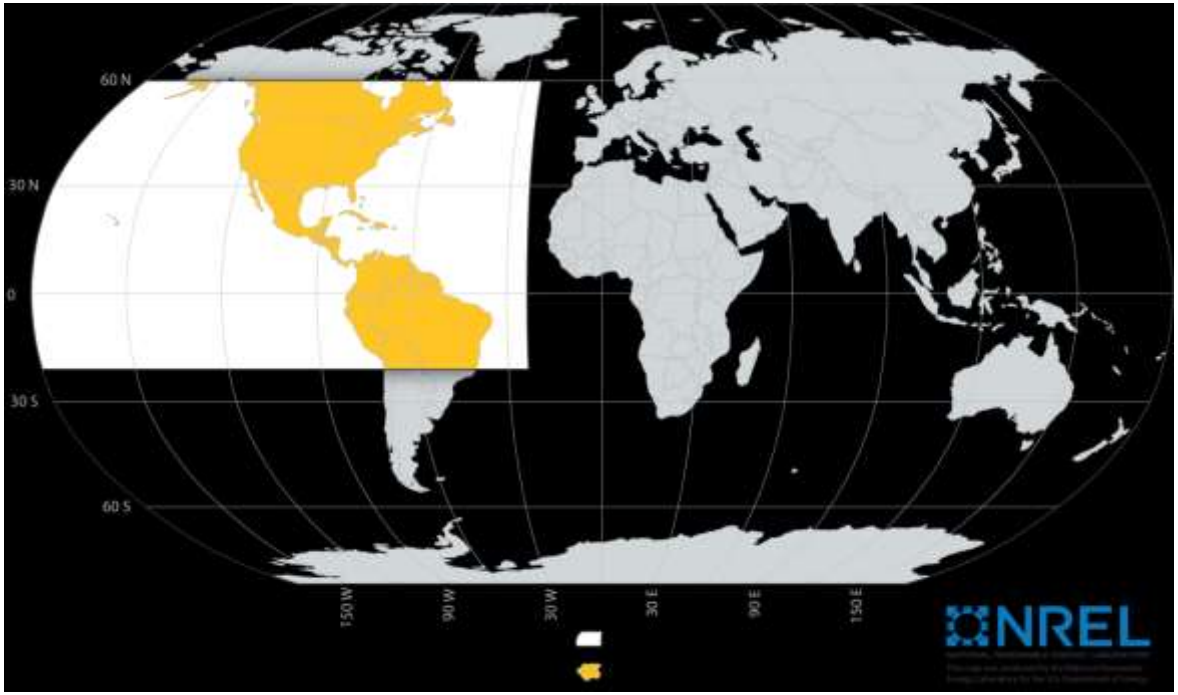
Validation of the PSM

- Evaluation of the new NSRDB dataset was carried out using high-quality SURFRAD ground stations



MBE in percent for all years (1998-2014) for the seven SURFRAD sites.

NSRDB



- The area covers 25° W to 175° W and 20° S to 60° N
- Includes **half-hourly** satellite modeled solar data for years 1998-2014 on **4-km** grid
- Time-series solar data for a location can be combined with hourly met data for PV and CSP simulation

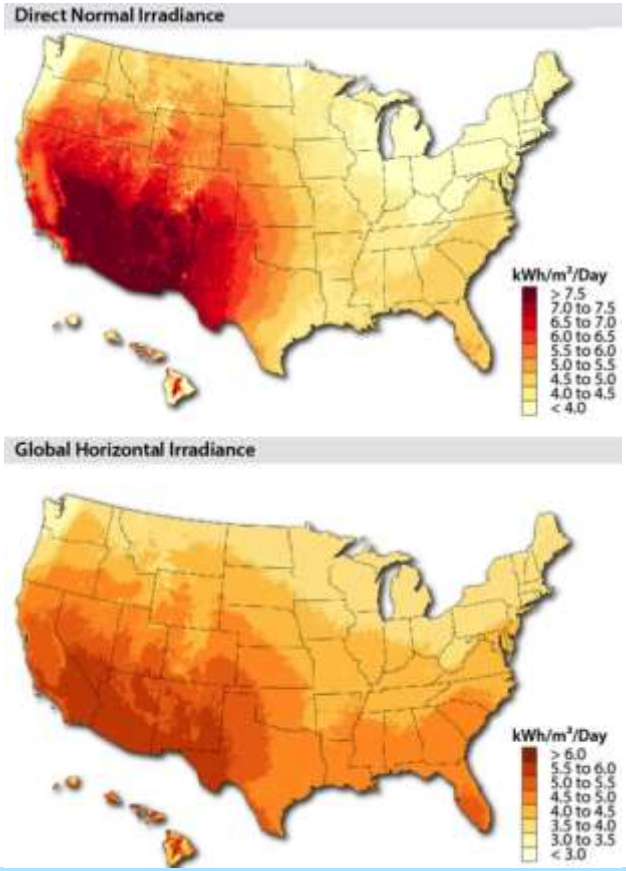
NSRDB Product Variables

Element	Unit	Description
Clearsky DHI	Watt per square meter	- Modeled solar radiation on a horizontal surface received from the sky excluding the solar disk. - **This is assuming clear sky condition**
Clearsky DNI	Watt per square meter	- Modeled solar radiation obtained from the direction of the sun. - **This is assuming clear sky condition**
Clearsky GHI	Watt per square meter	- Modeled solar radiation on a horizontal surface received from the sky. - **This is assuming clear sky condition**
Cloud Type	Unitless	Obtained from PATMOS-X
Dew Point	Degree C	Calculated from specific humidity
DHI	Watt per square meter	Modeled solar radiation on a horizontal surface received from the sky excluding the solar disk.
DNI	Watt per square meter	Modeled solar radiation obtained from the direction of the sun.
GHI	Watt per square meter	Modeled solar radiation on a horizontal surface received from the sky.
Fill Flag	Unitless	'N/A': 0, 'Missing Image': 1, 'Low Irradiance': 2, 'Exceeds Clearsky': 3, 'Missing Cloud Properties': 4, 'Rayleigh Violation': 5
Snow Depth	meters	Source: MERRA
Solar Zenith Angle	Degrees	Angle between the sun and the zenith
Temperature	Degree C	Source: MERRA
Pressure	Millibar	Source: MERRA
Relative Humidity	Percent	Calculated from specific humidity
Precipitable Water	Millimeter	Source: MERRA
Wind Direction	Degrees	Source: MERRA
Wind Speed	meter per second	Source: MERRA

TMY

Gridded TMY - Developed using the gridded NSRDB (1998-2014)

Step 1	Step 2	Step 3	Step 4
5 candidate months with cumulative distribution functions (CDFs) for the daily indices that are closest to the long-term (30 years for the NSRDB) CDFs are selected.	The 5 candidate months are ranked with respect to closeness of the month to the long-term mean and median.	The persistence of mean dry bulb temperature and daily global horizontal radiation are evaluated by determining the frequency and run length above and below fixed long-term percentiles.	The 12 selected months are concatenated to make a complete year.



TMY data sets provide industry standard resource information for:

- Building design and performance
- Solar heating and cooling systems
- Photovoltaic and concentrating solar power system performance
- Energy systems analysis

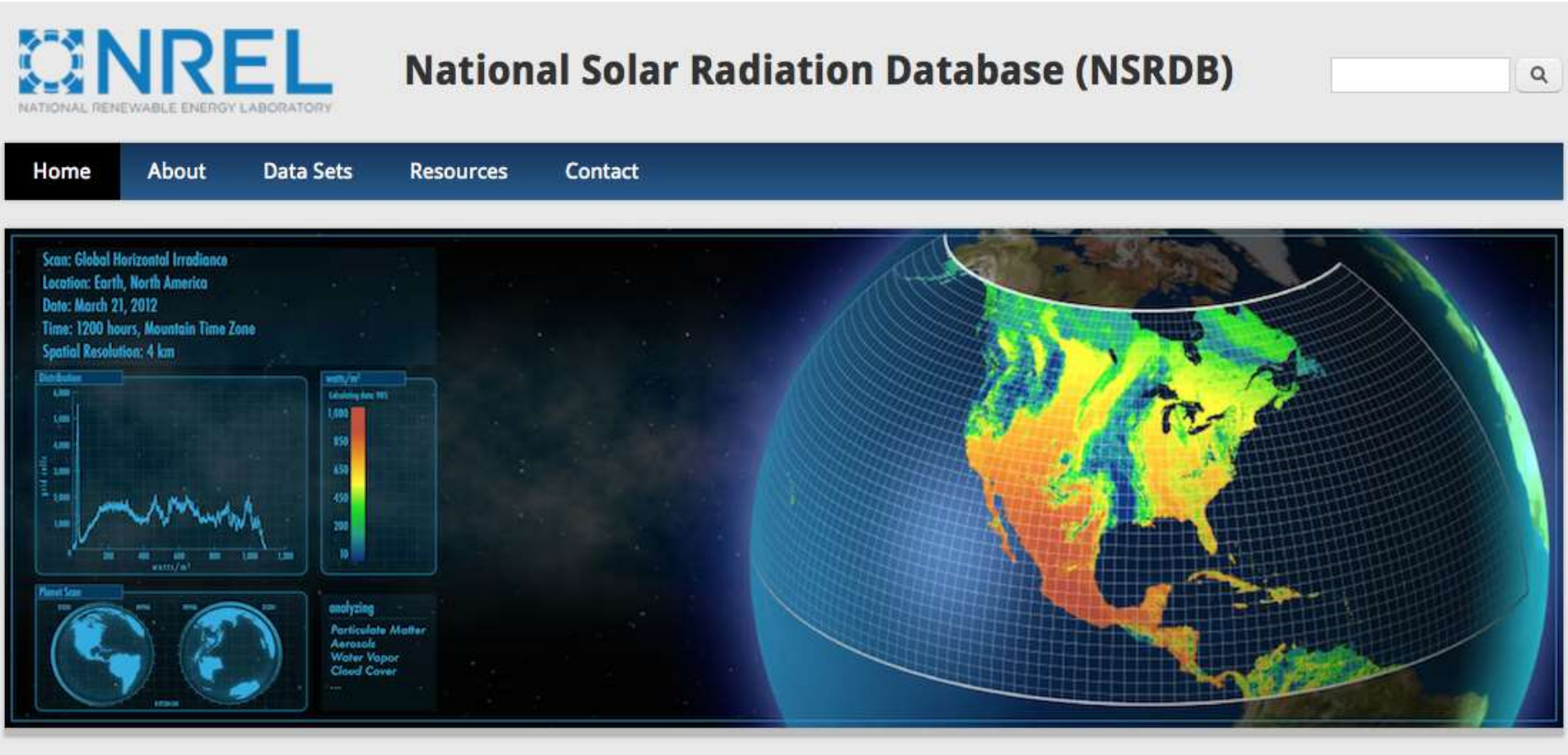
Example figures representing DNI and GHI datasets for TMY developed using meteorological and irradiance weighting factors.

TMY Product Variables

Element	Unit or Description
Year	1998-2014
Month	1-12
Day	1-28,1-30 or 1-31
Hour	1-23
Minute	0
Dew Point	Degree C
DHI	Watt per square meter
DNI	Watt per square meter
GHI	Watt per square meter
Temperature	Degree C
Pressure	Millibar
Wind Direction	Degrees
Wind Speed	meter per second

NSRDB Website & Data Access

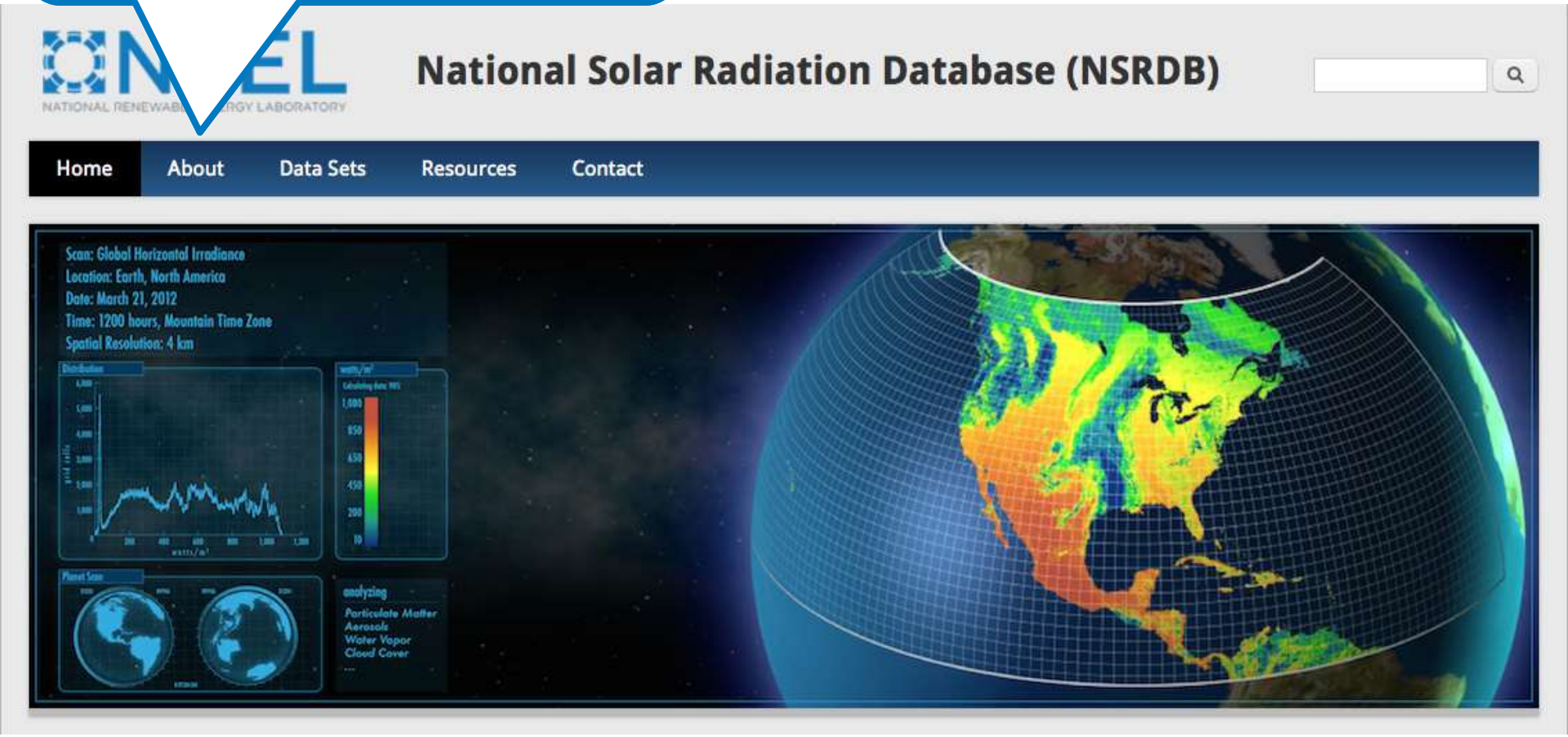
New NSRDB Website



http://nsrdb.nrel.gov

New NSRDB Website

Learn about the current and historic datasets, TMY, history, and more



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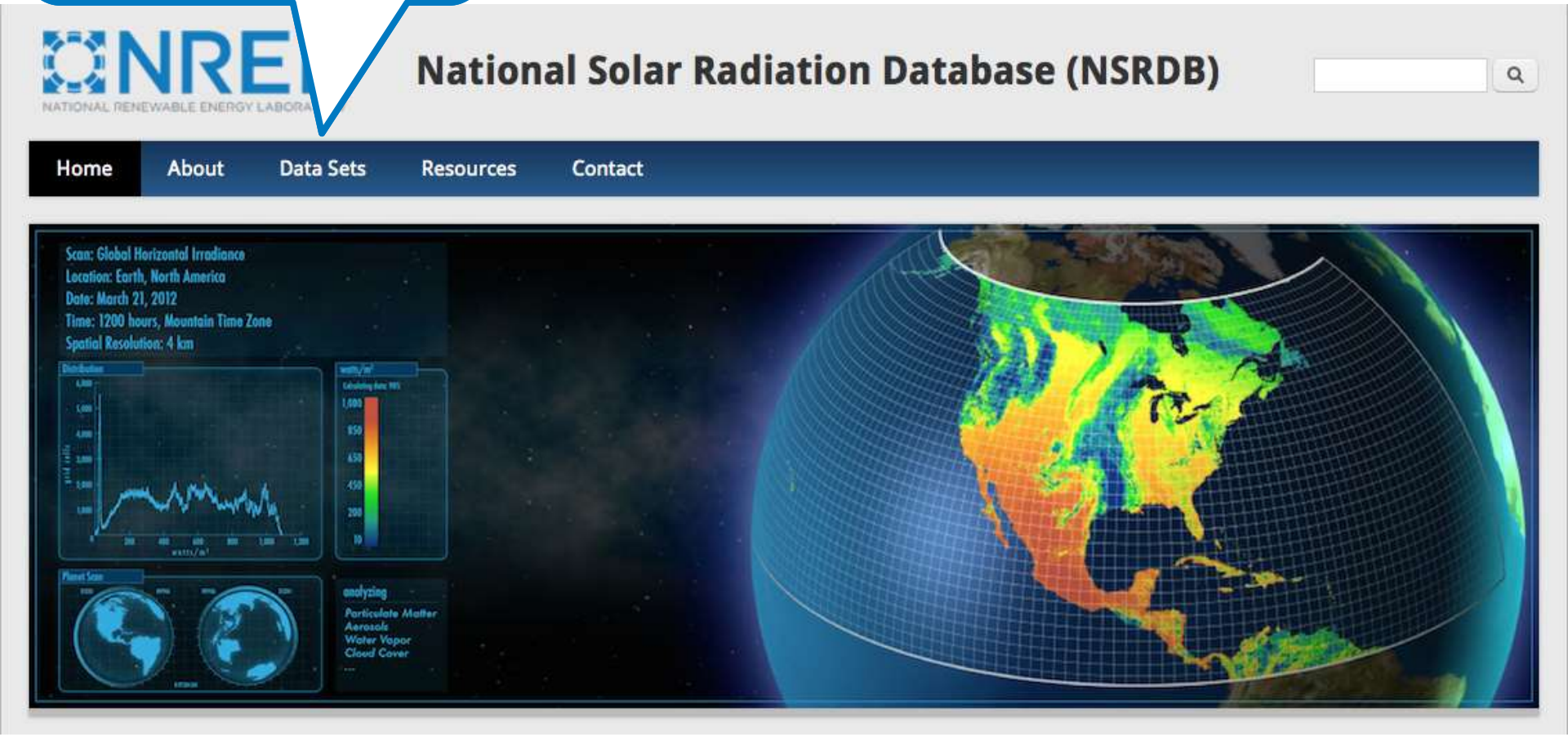
New NSRDB Website

Access the data



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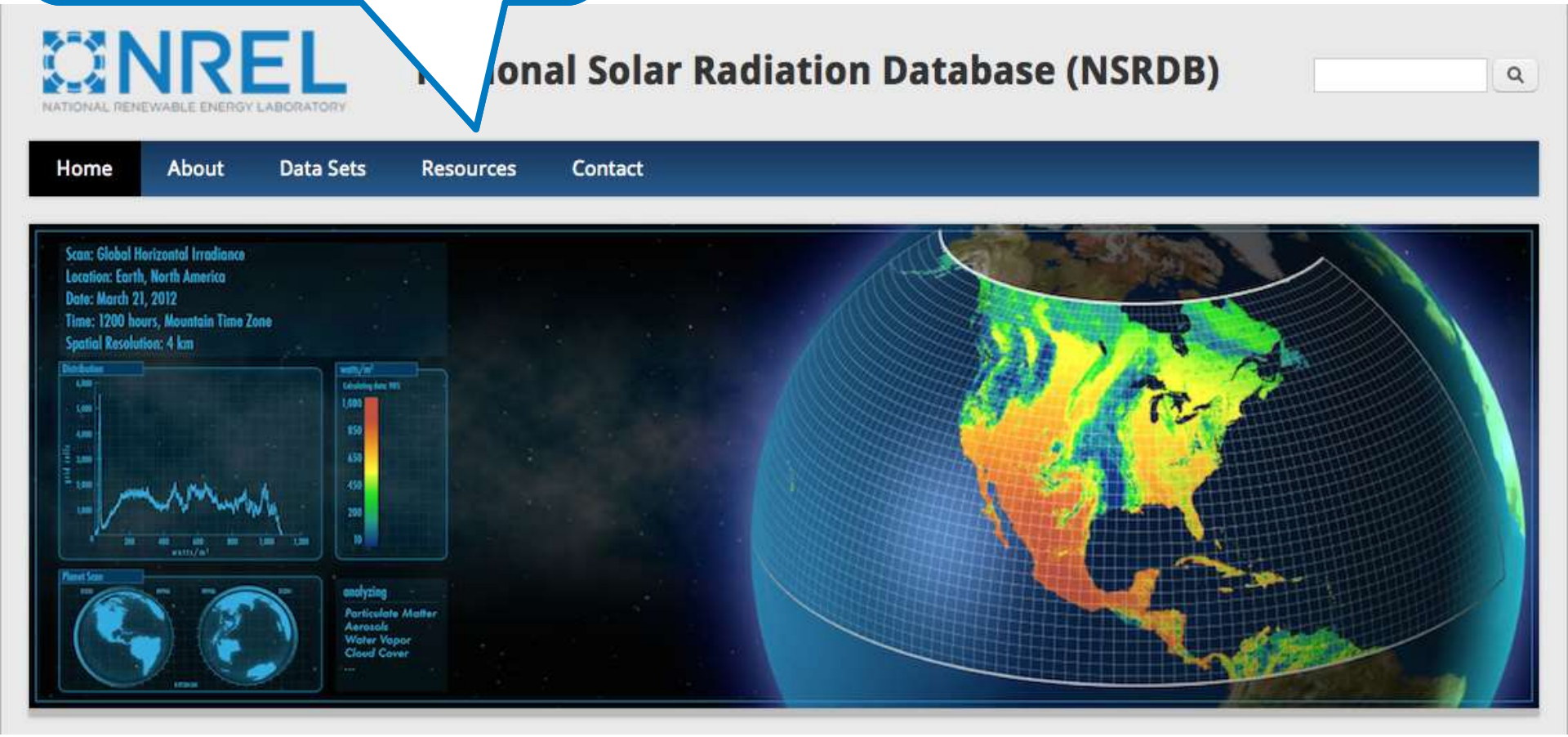
New NSRDB Website

Users manuals, helpful links, **publications**, and a user forum



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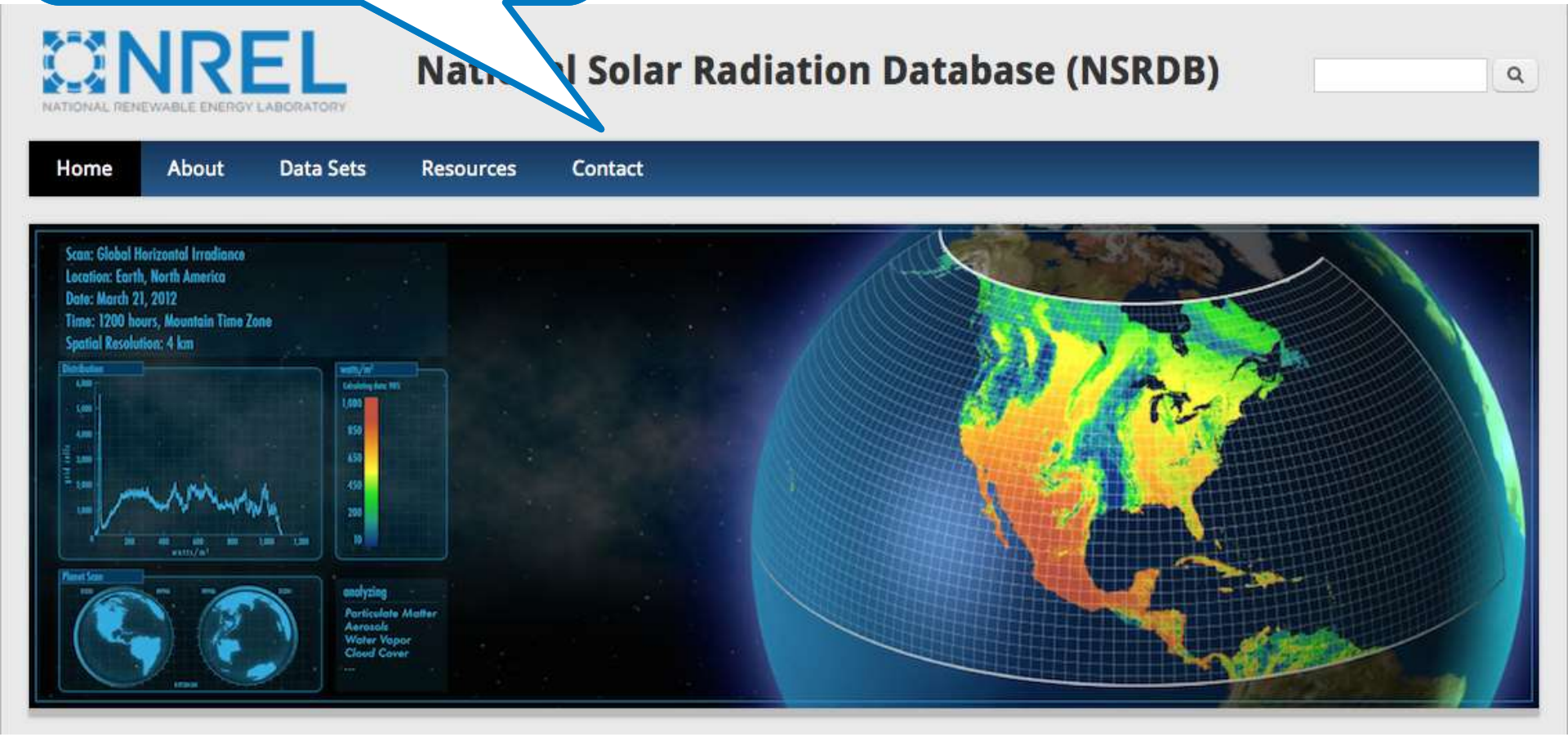
New NSRDB Website

Still have questions?
Contact us.



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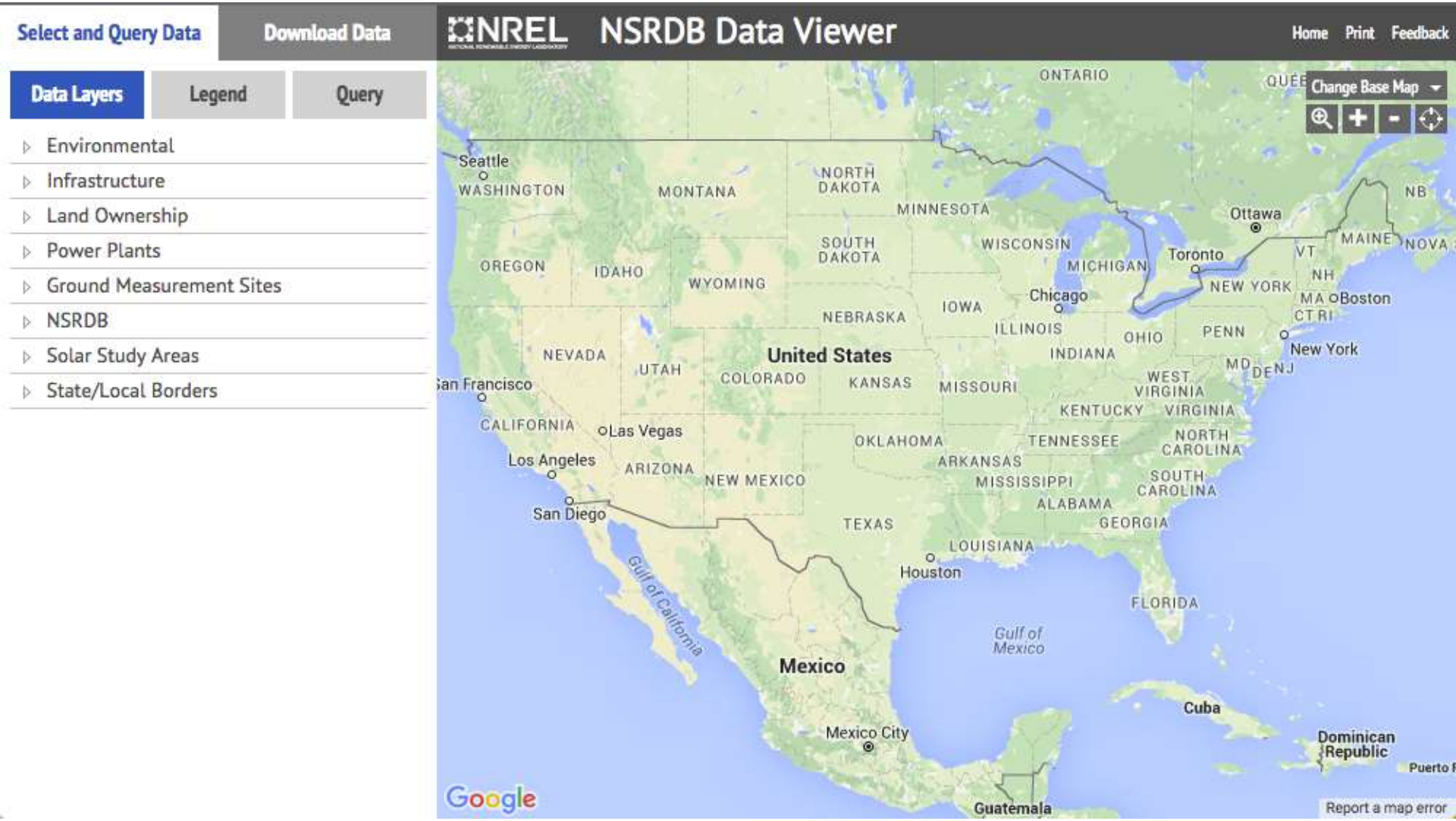
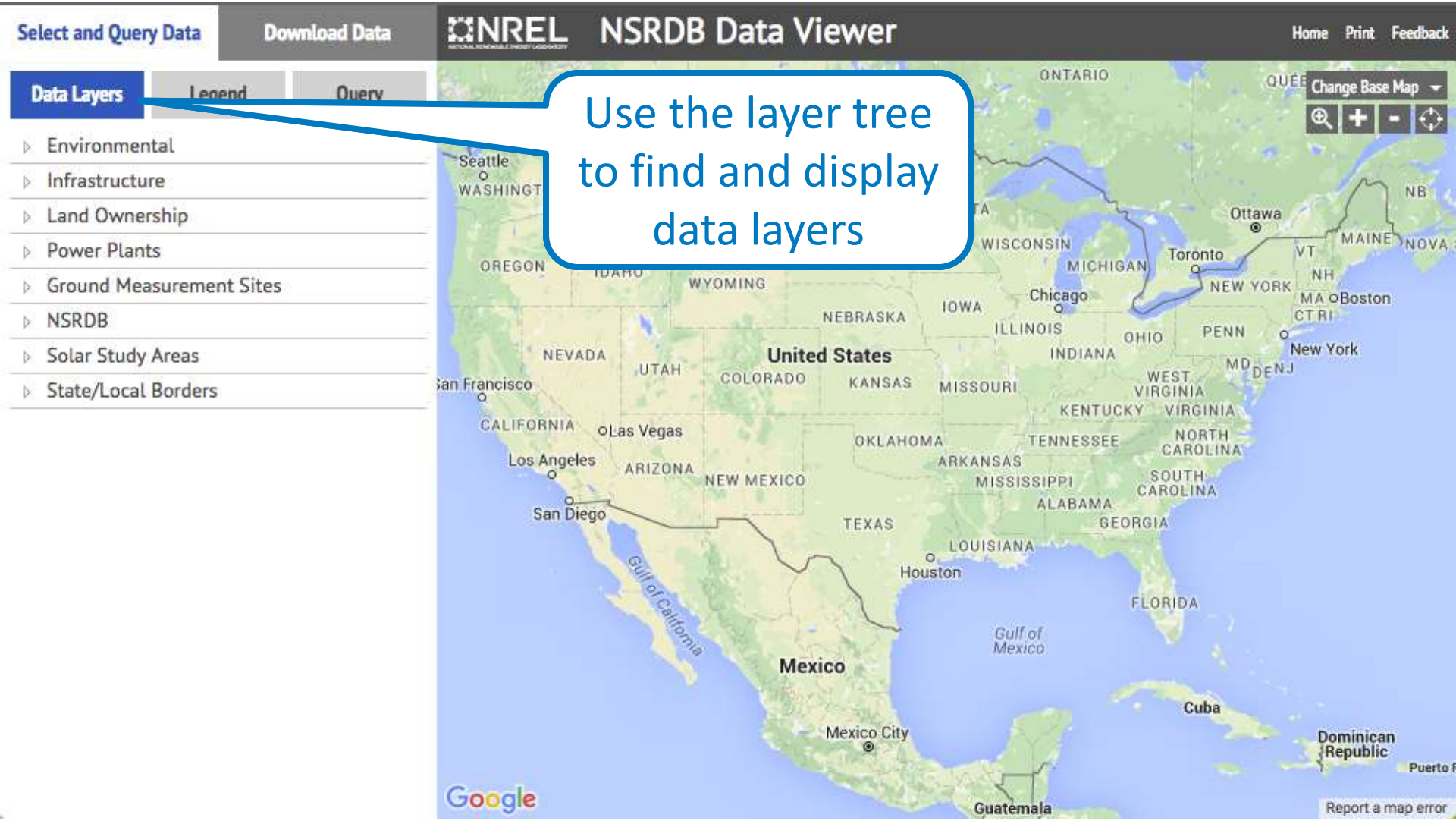
New NSRDB Viewer



Browse Data Layers



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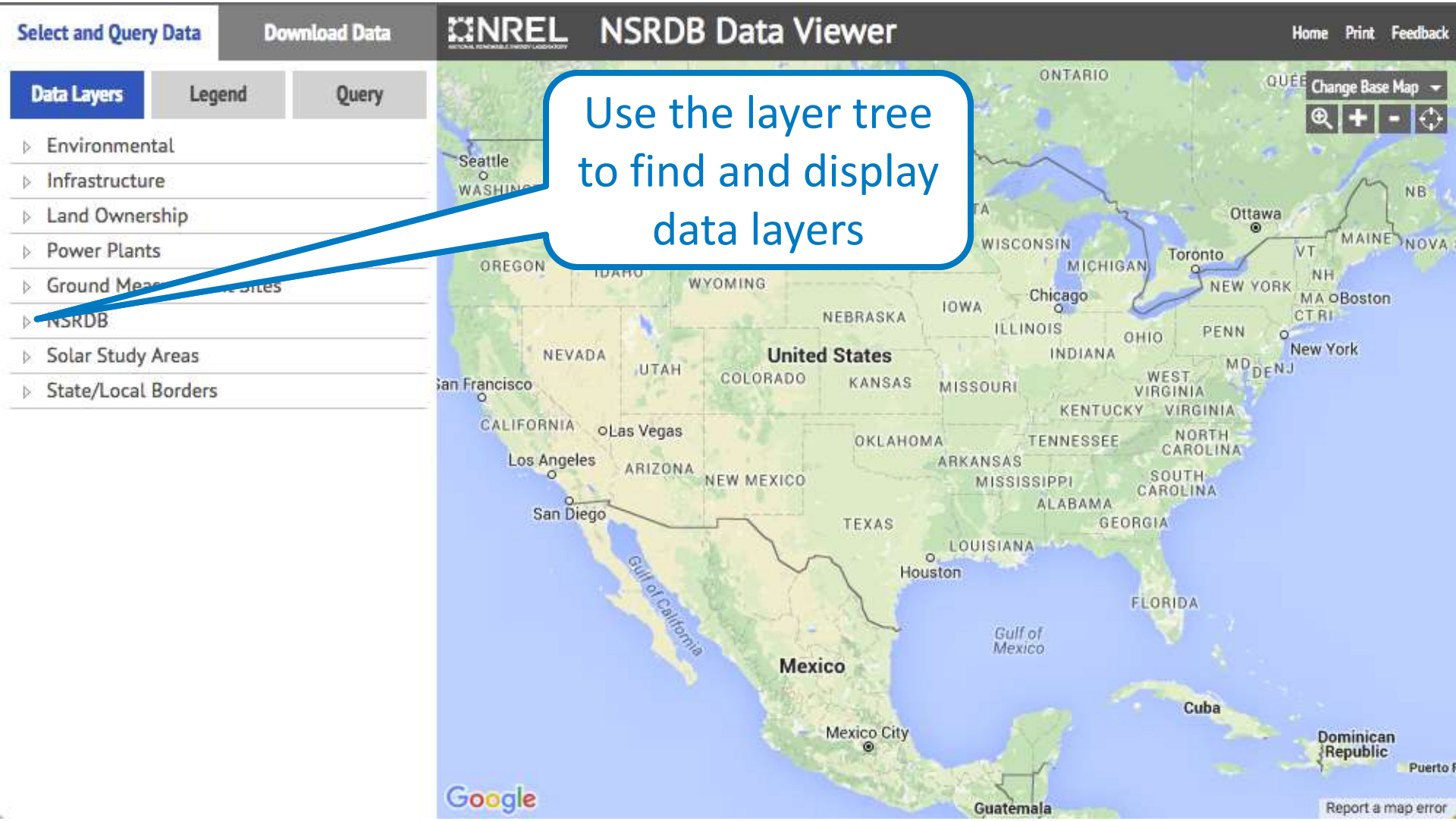

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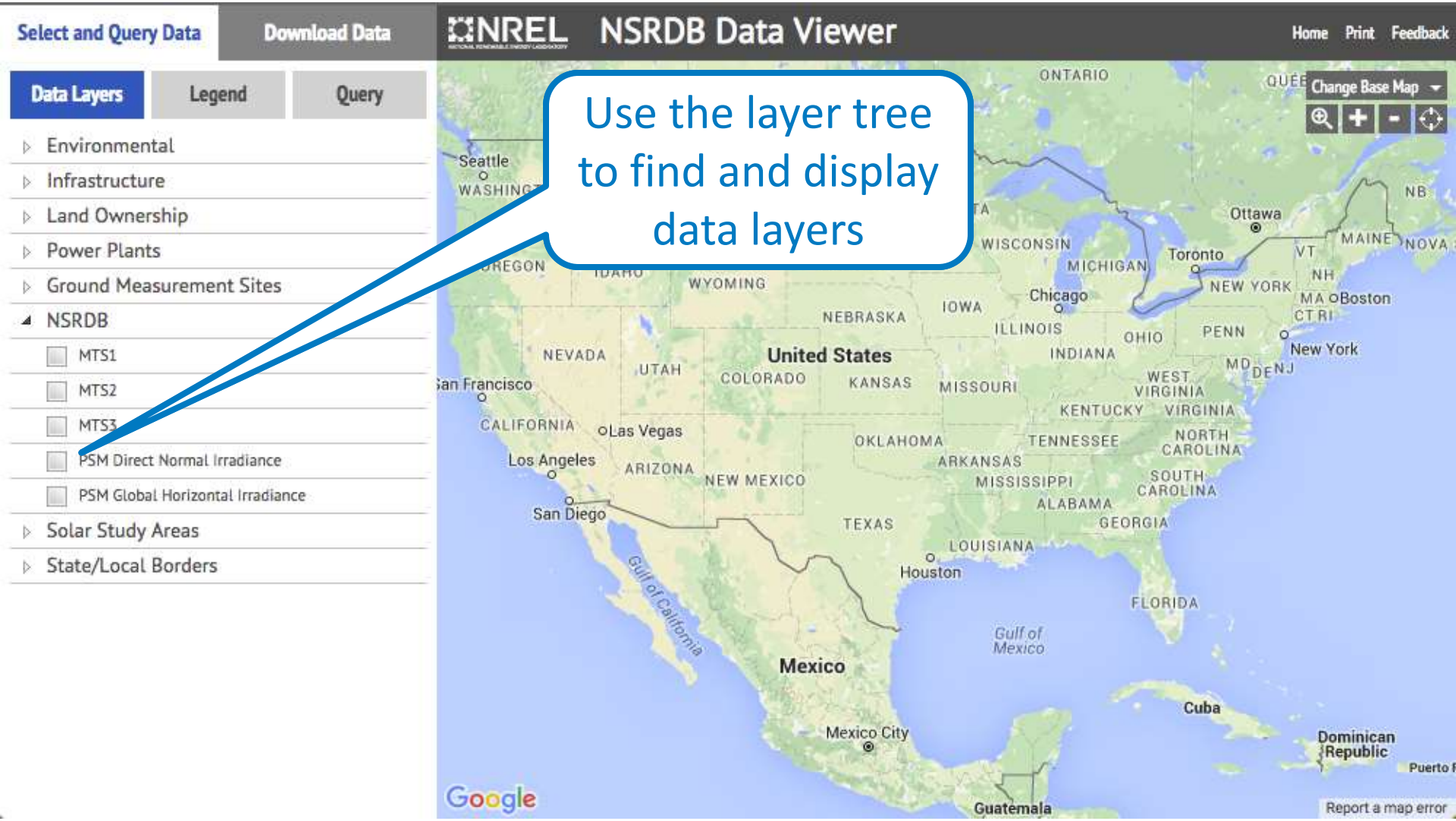

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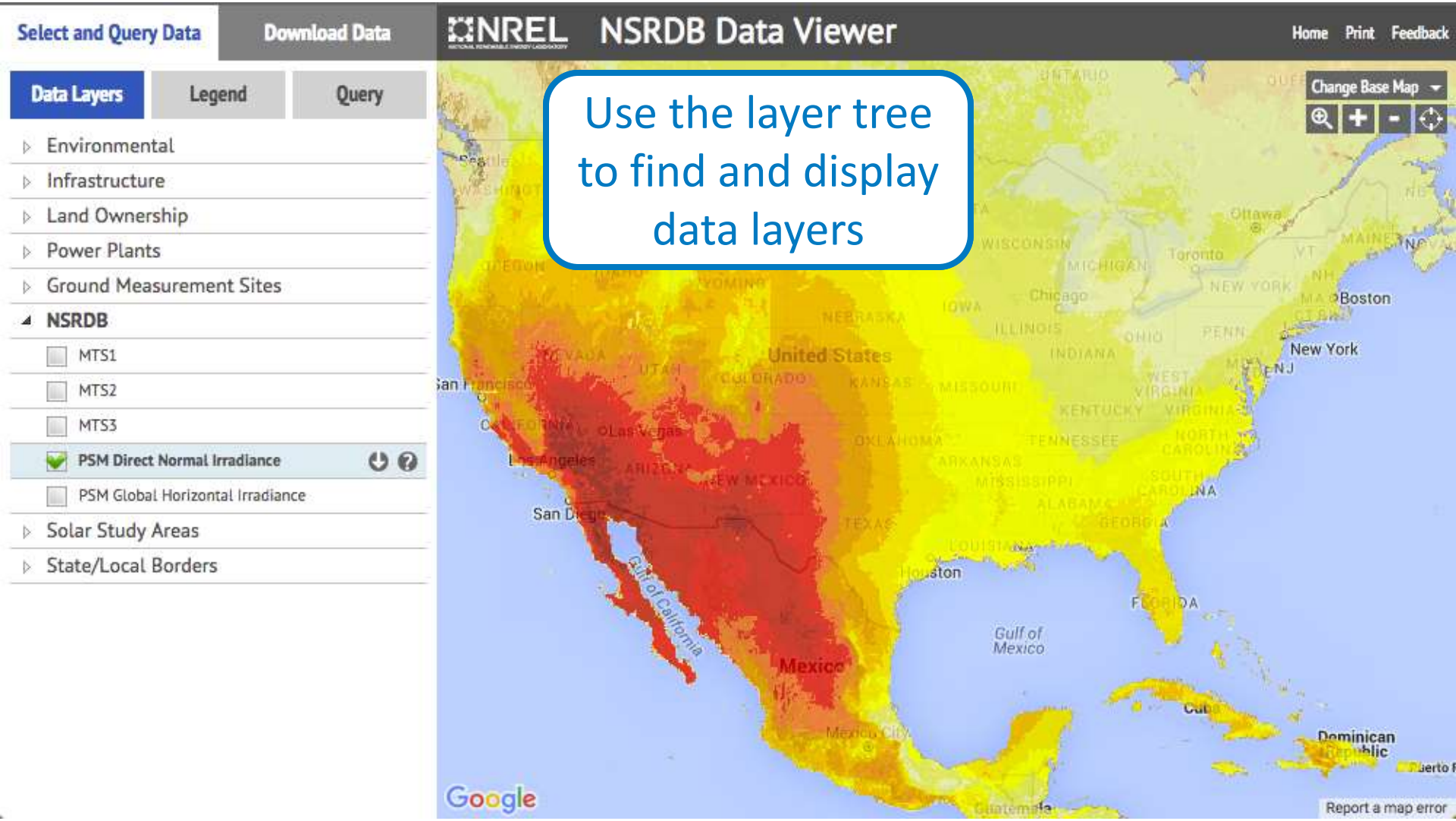

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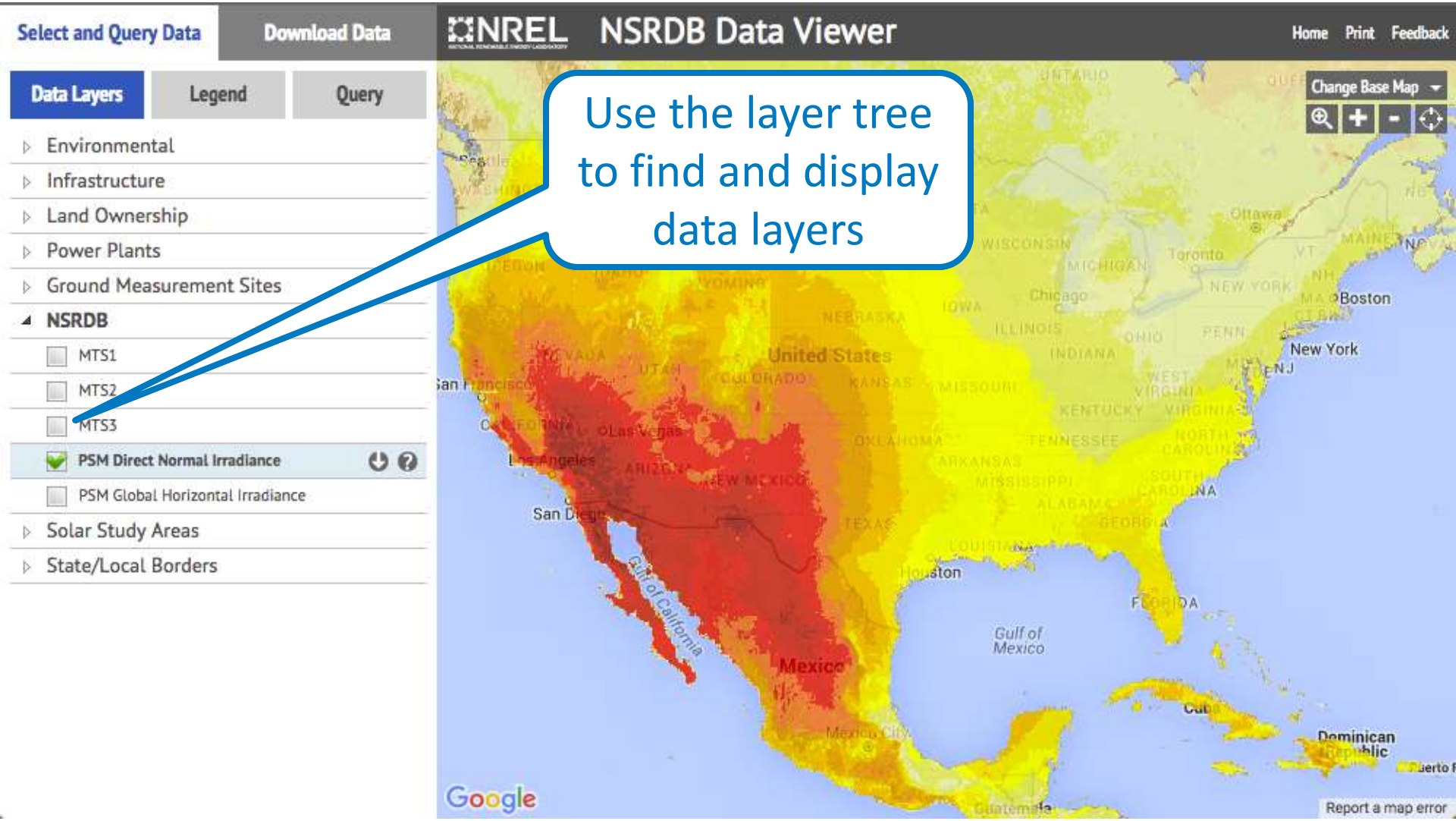

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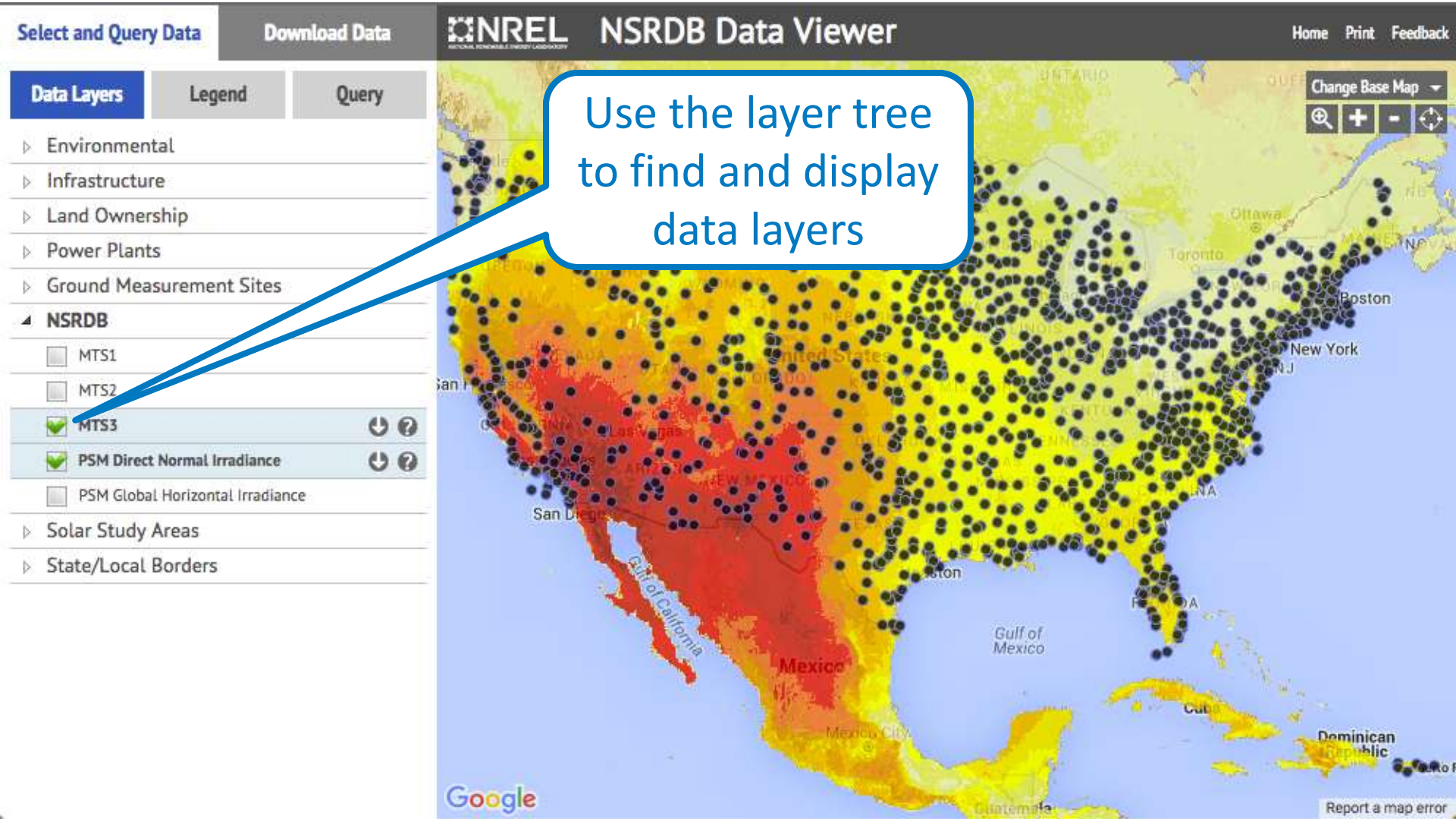

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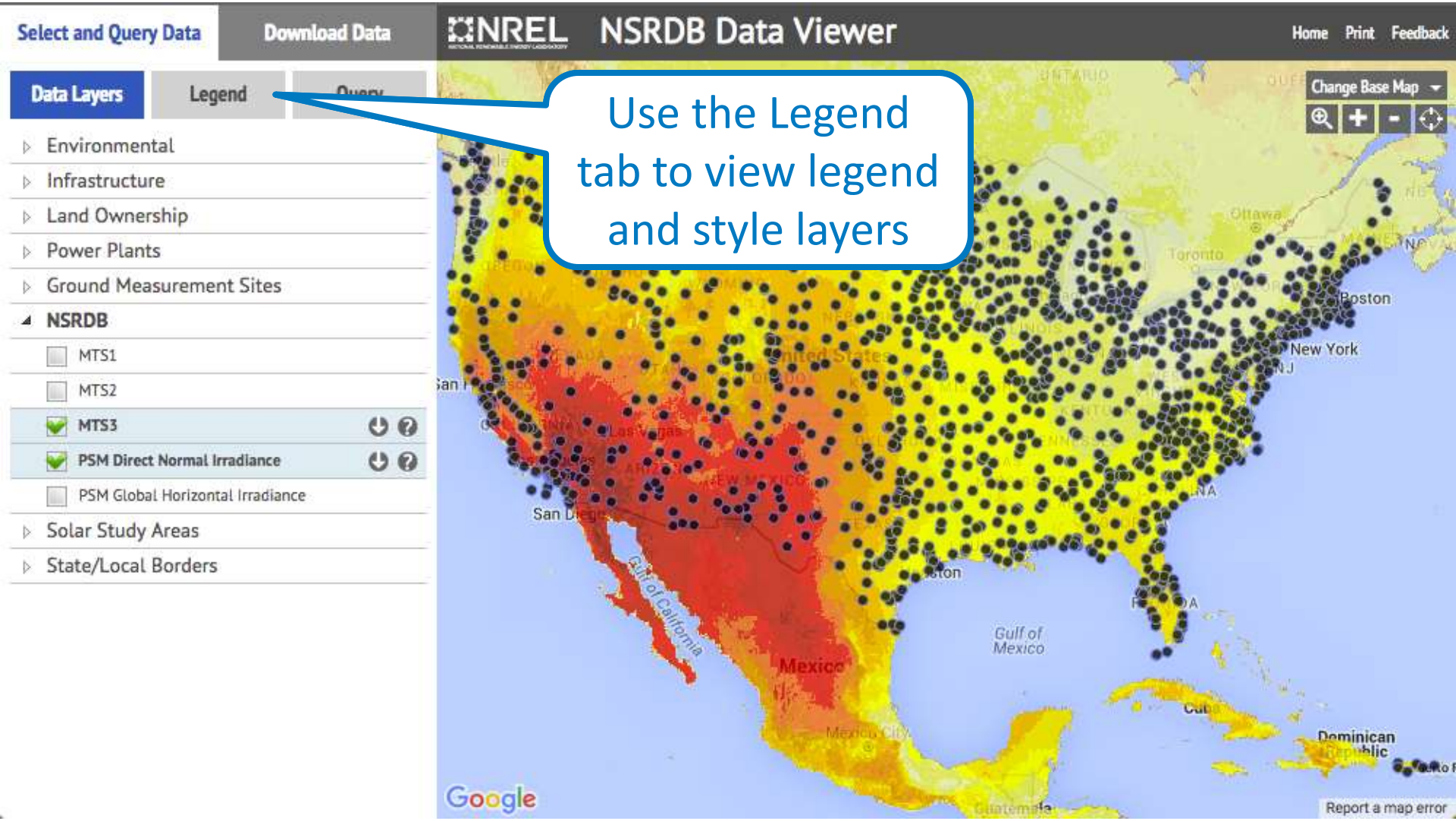

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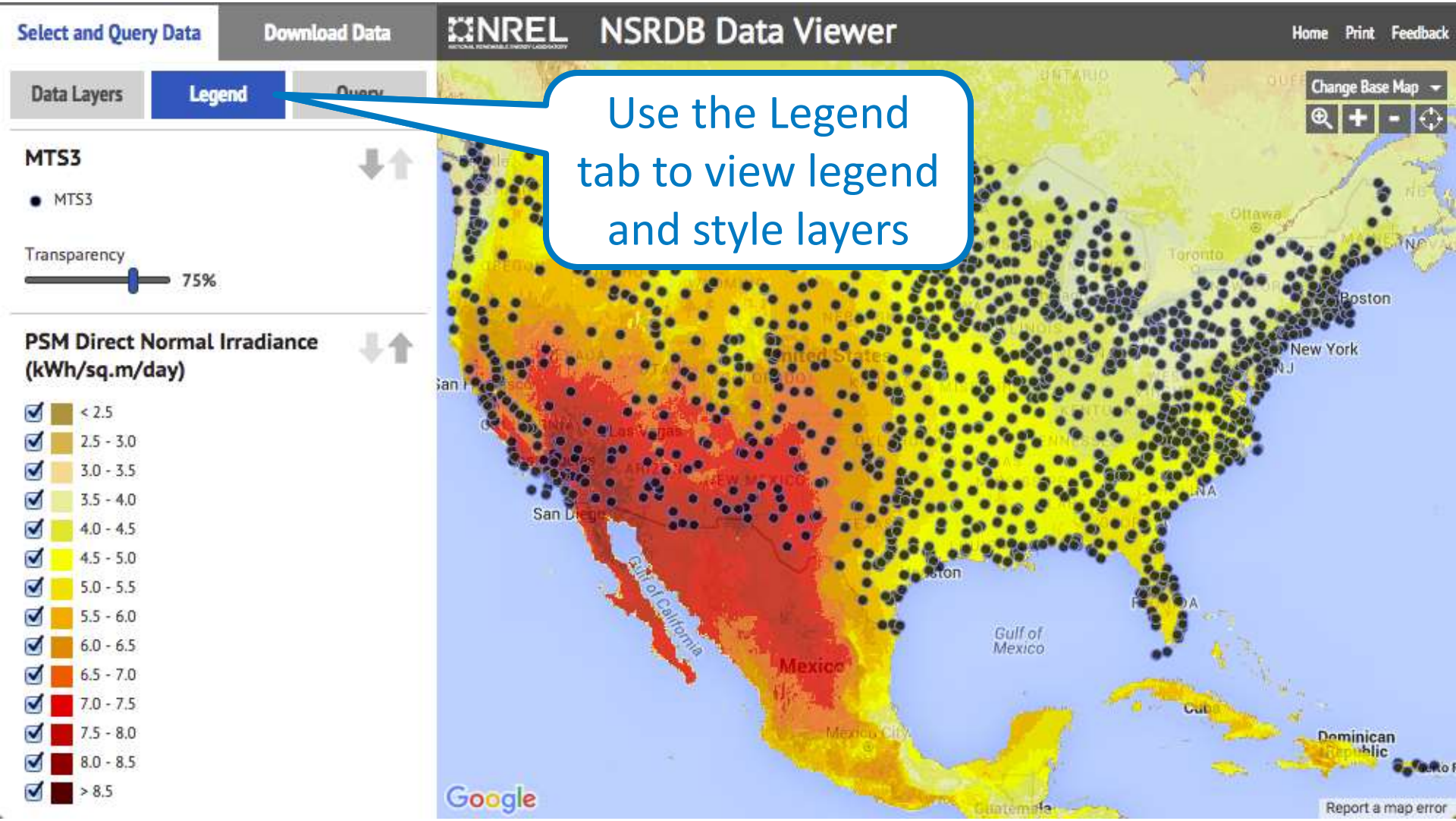

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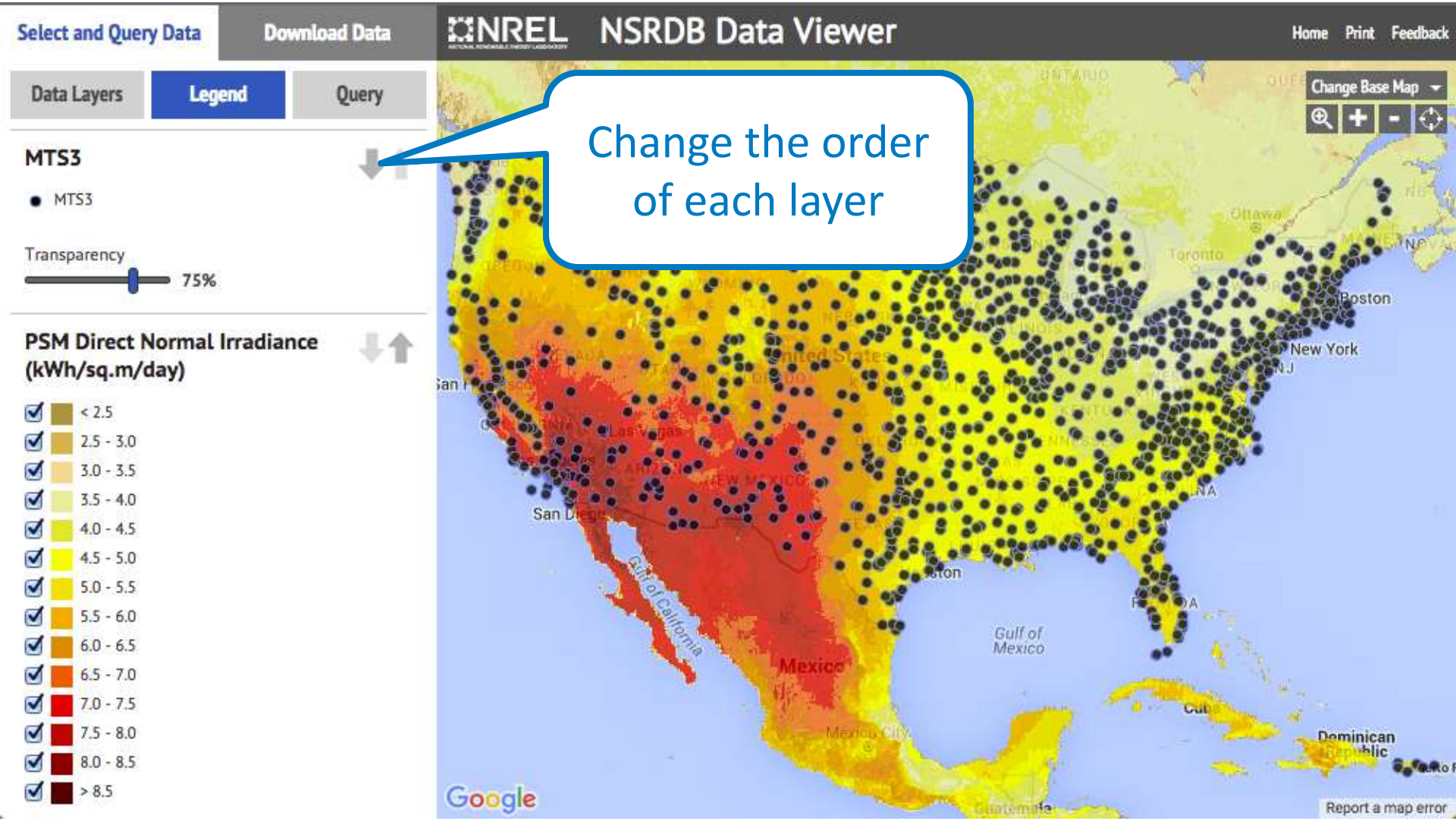

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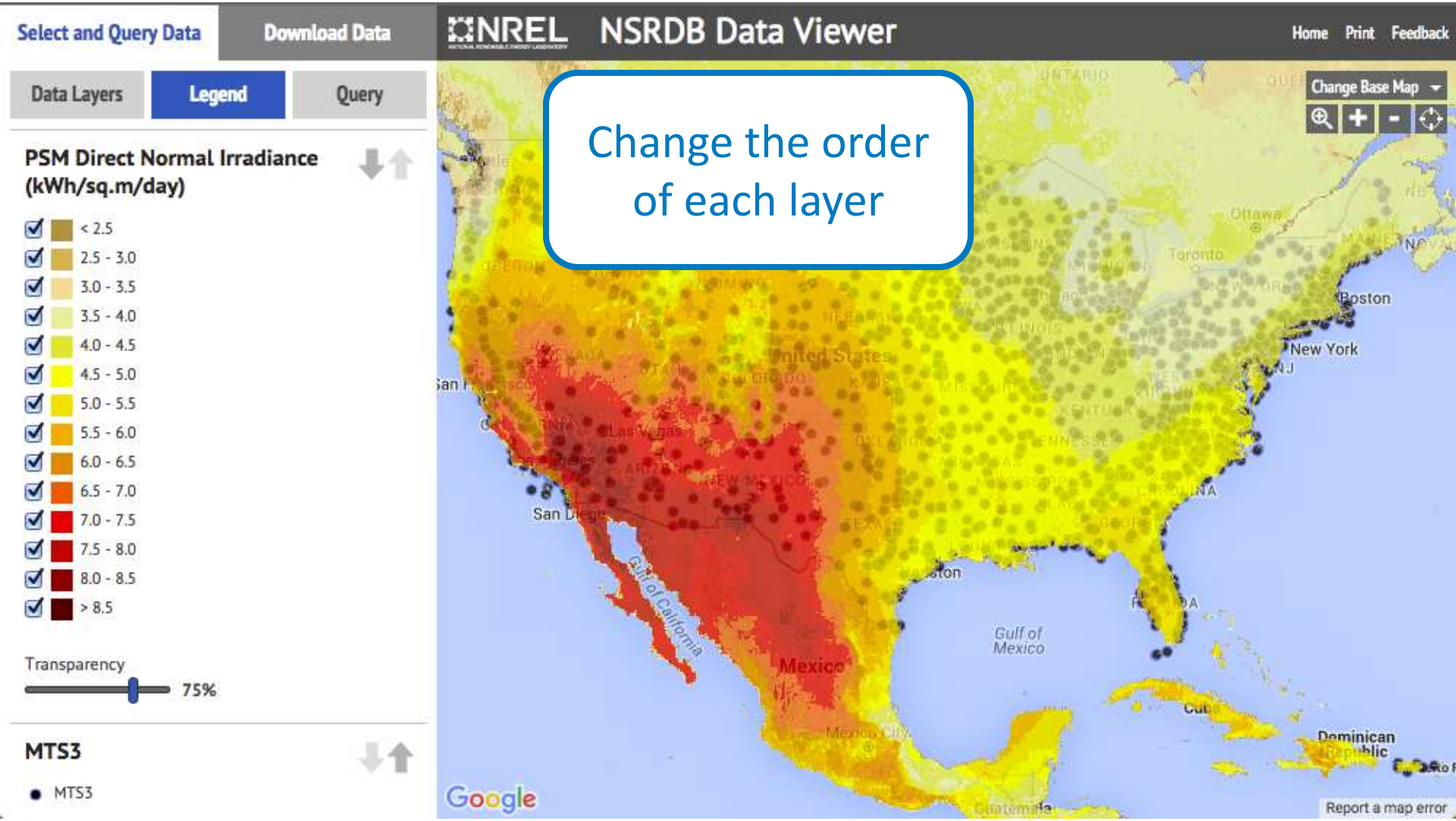

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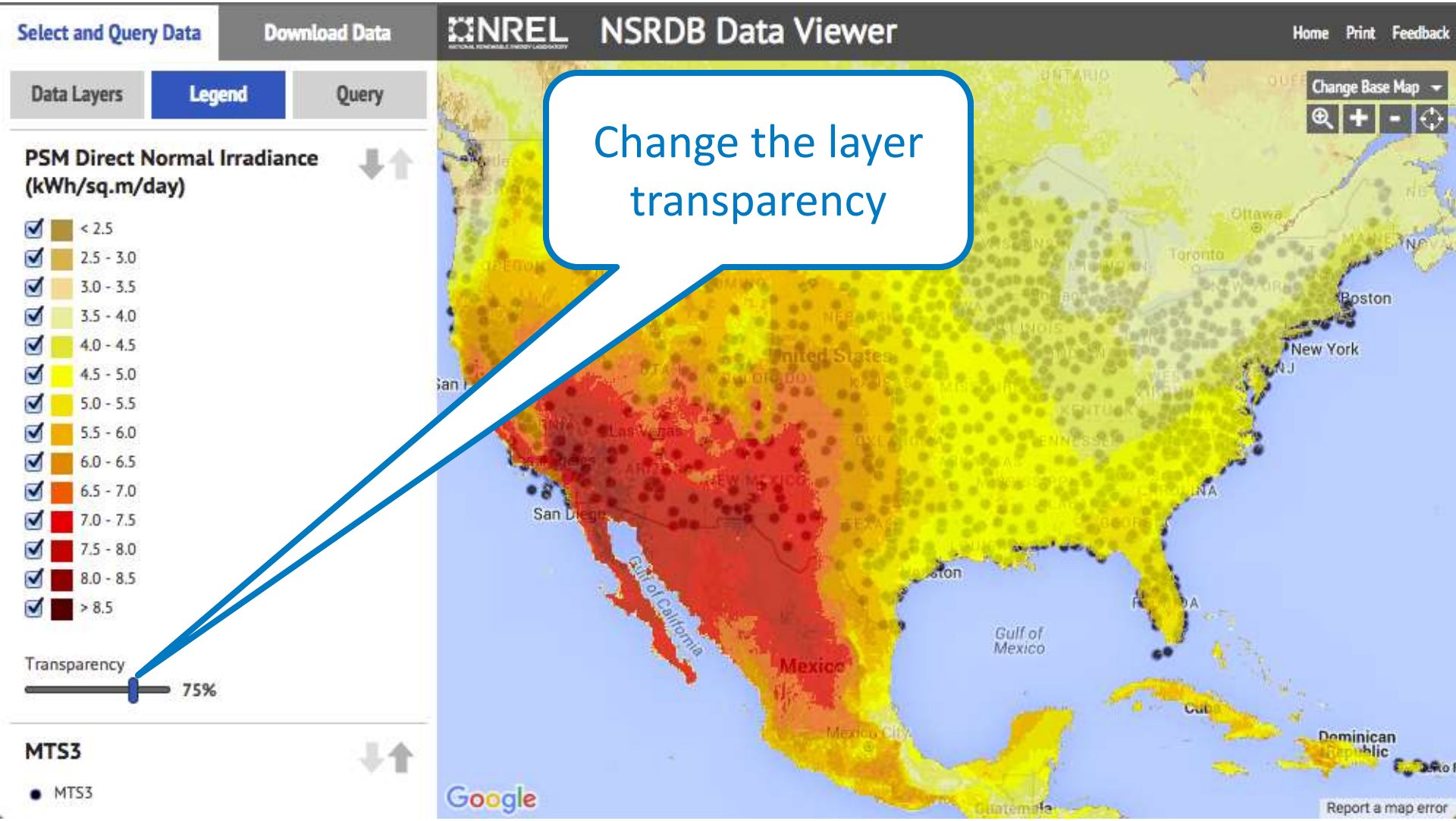
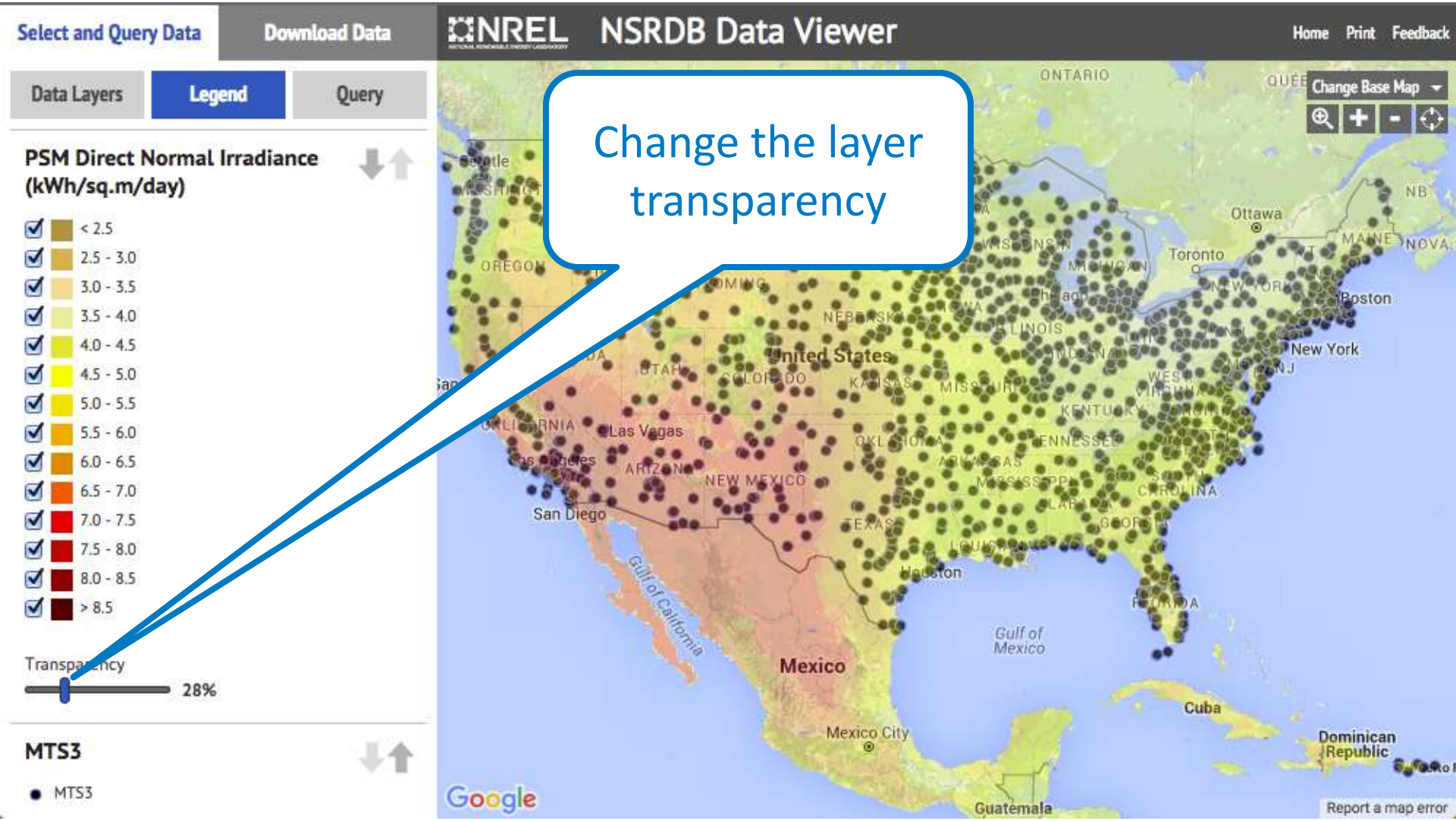
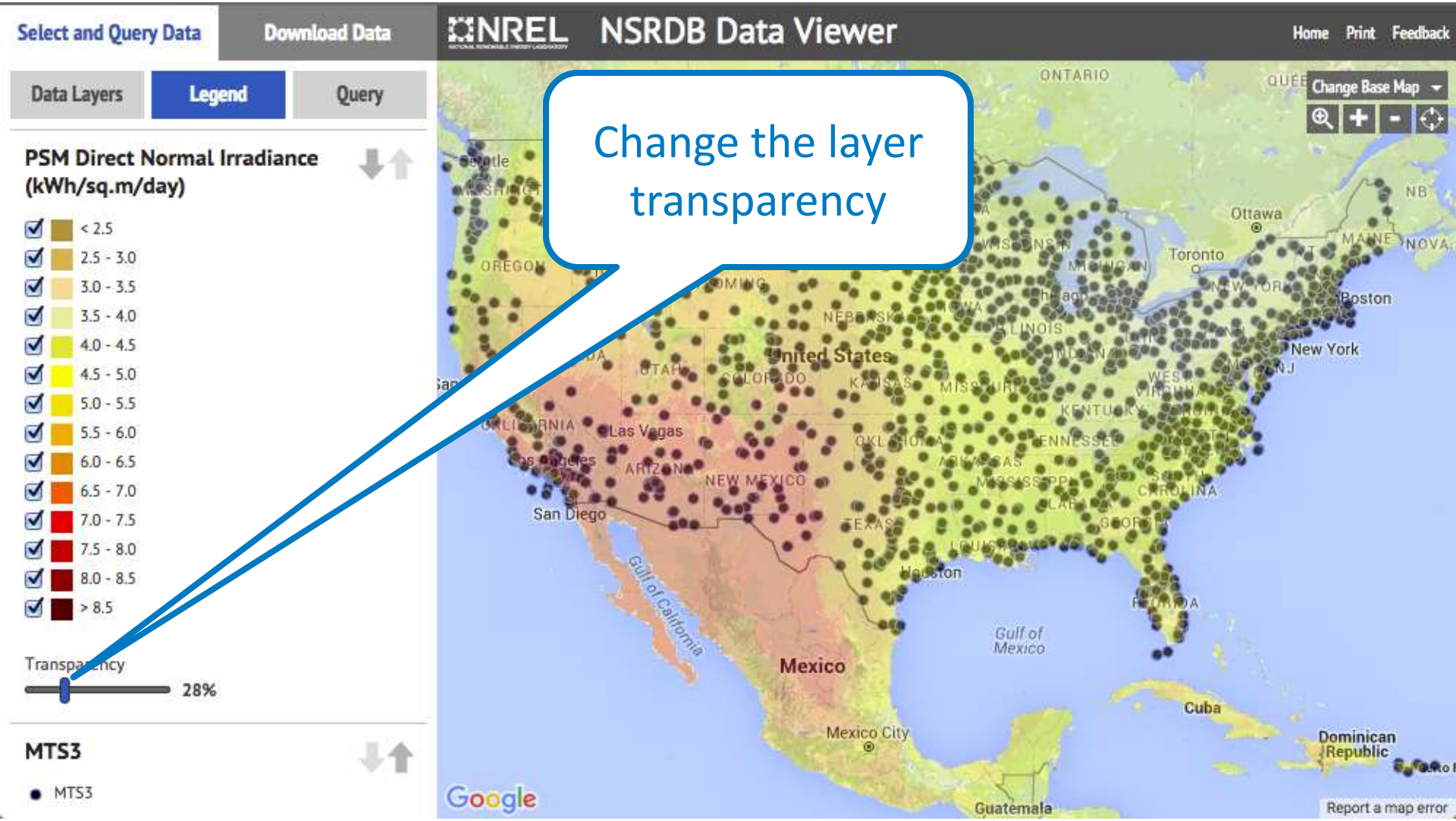


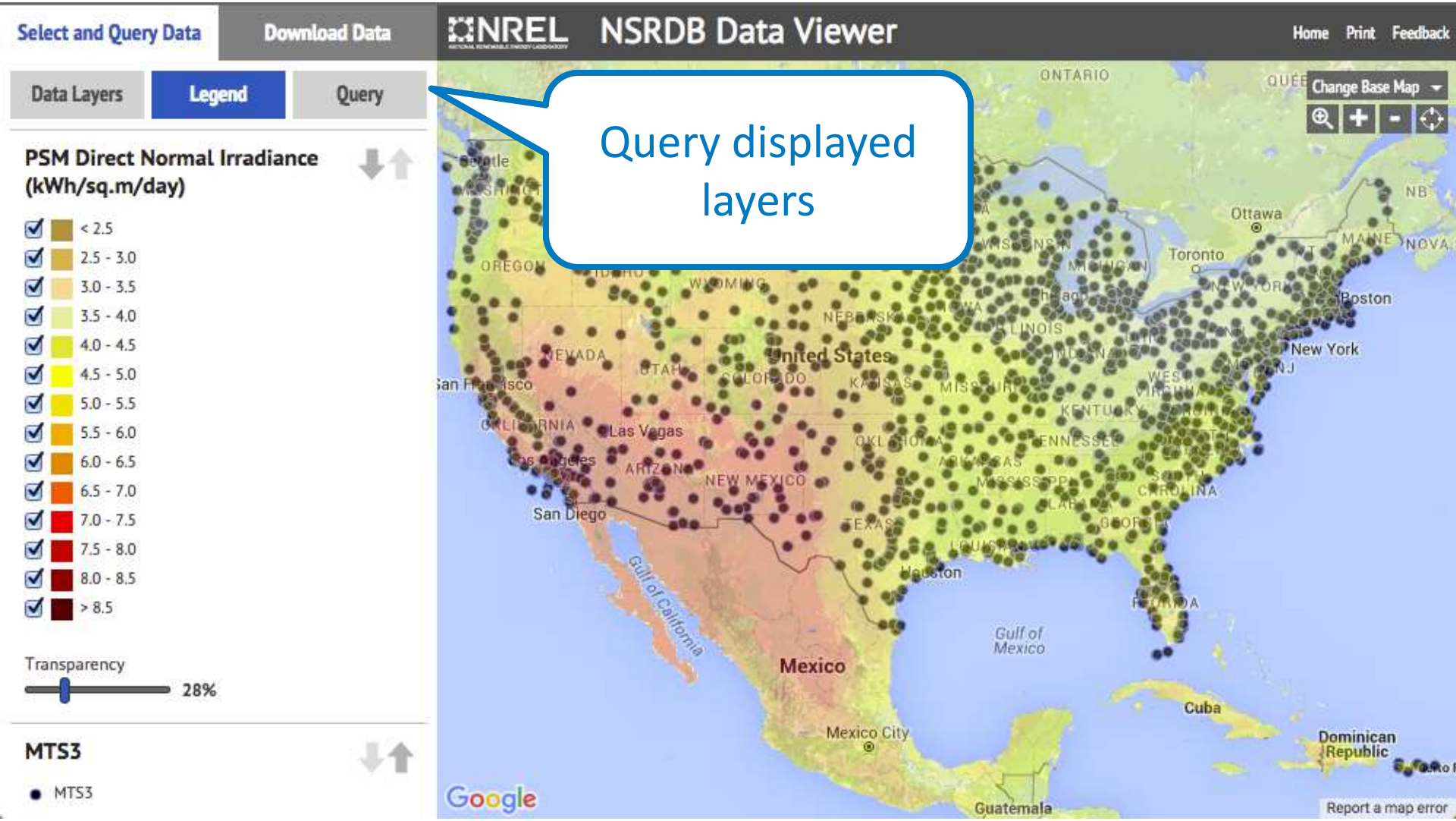
Browse Data Layers



Browse Data Layers



Query Data Layers



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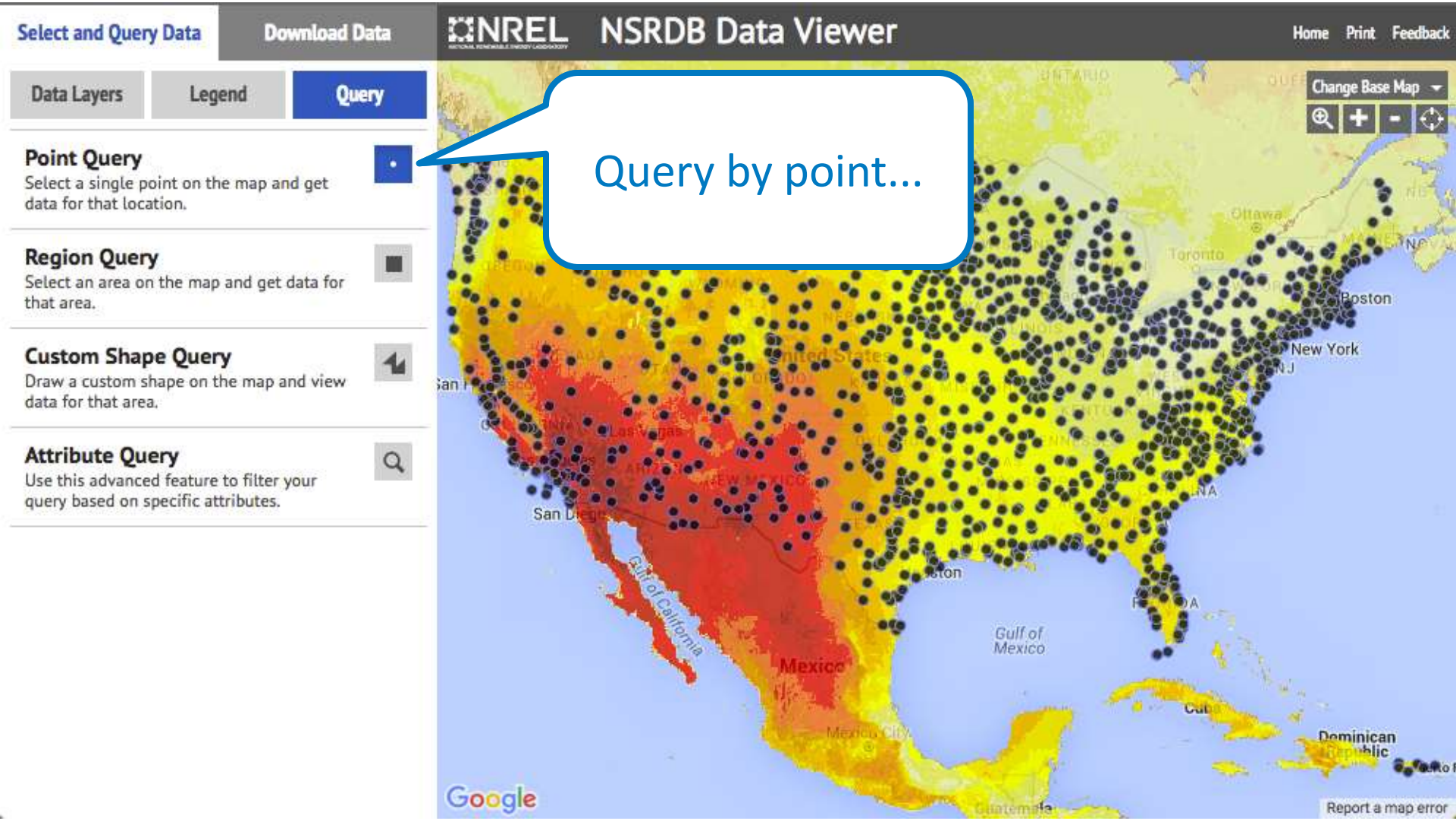

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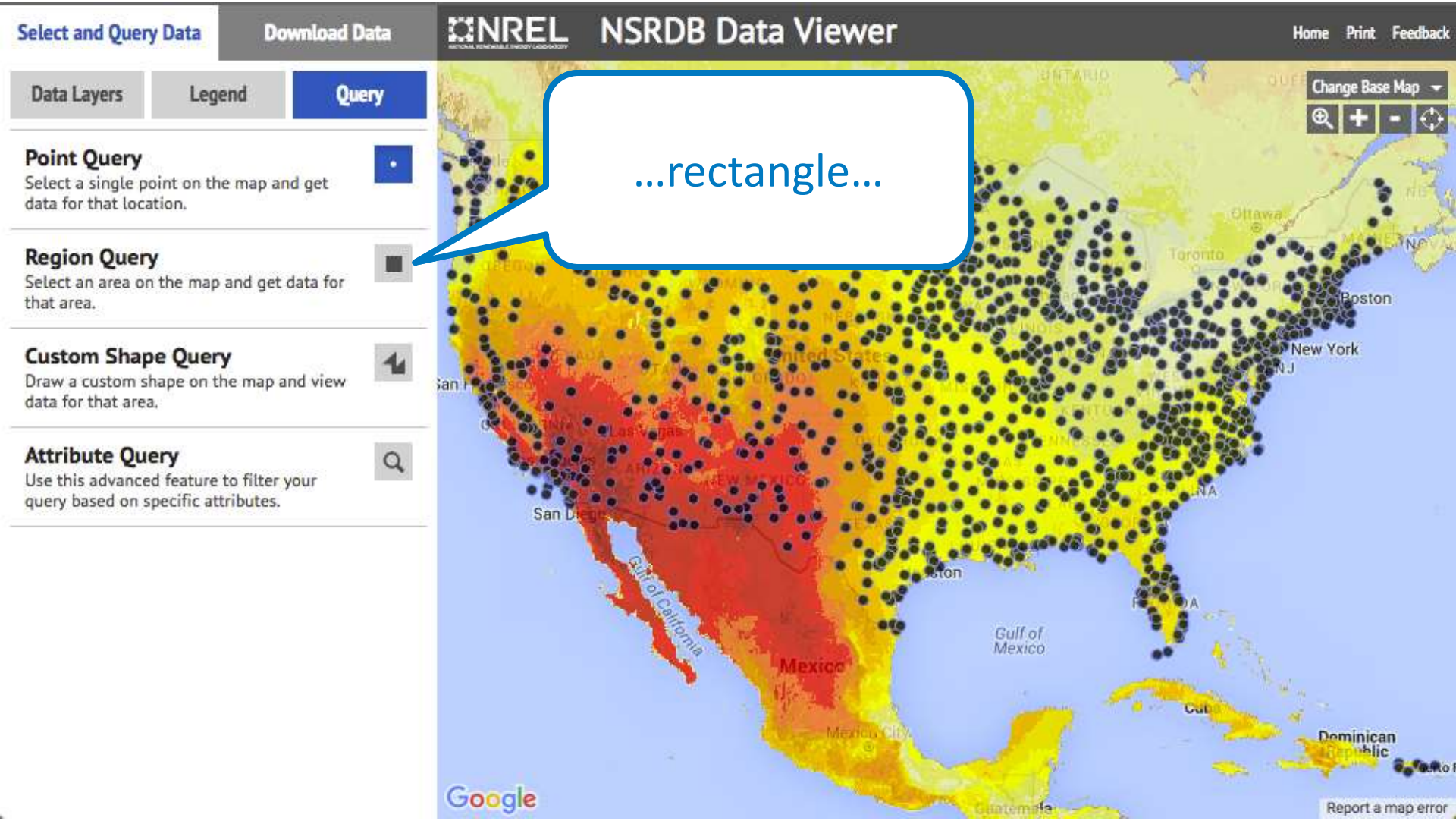
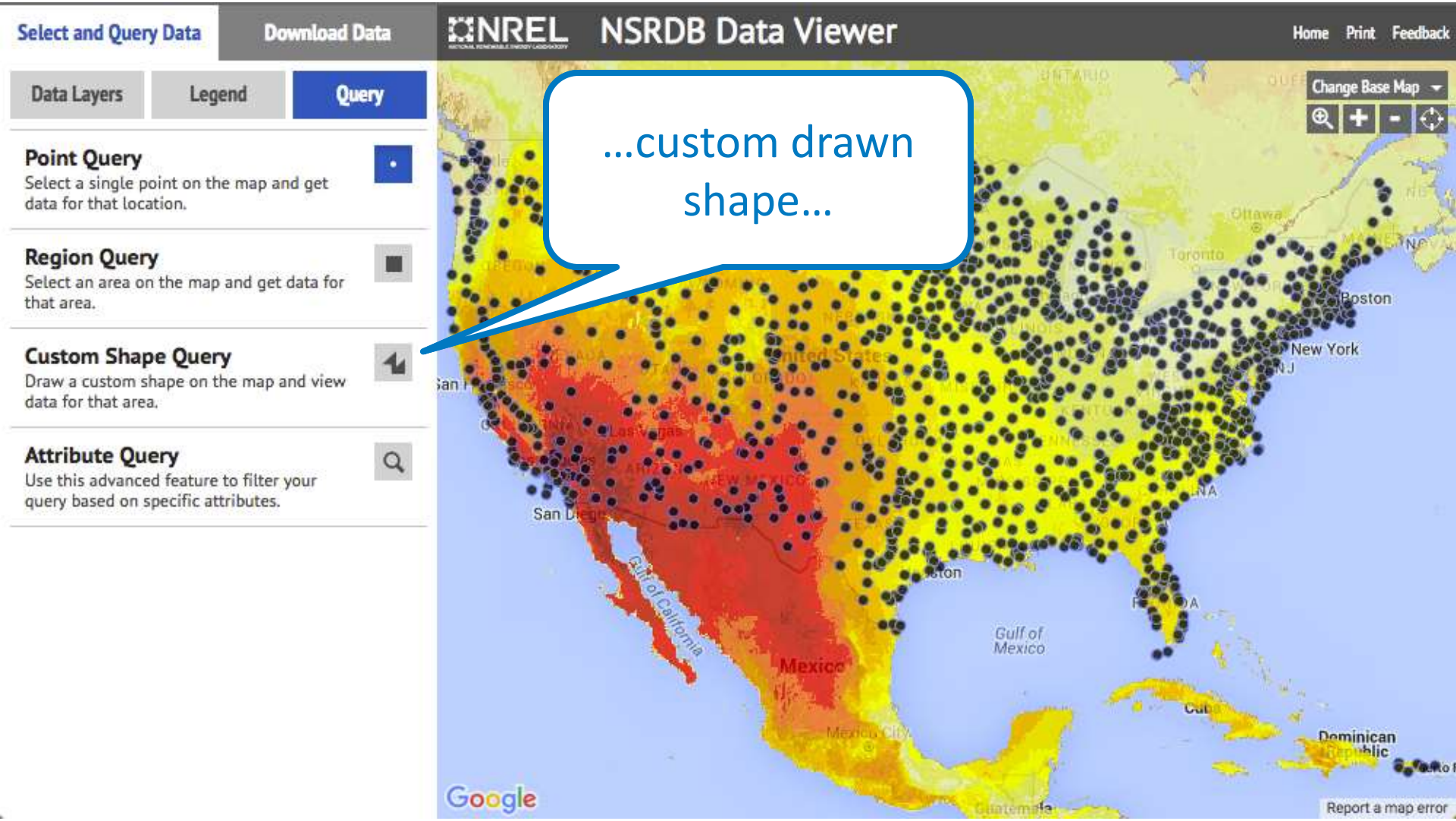
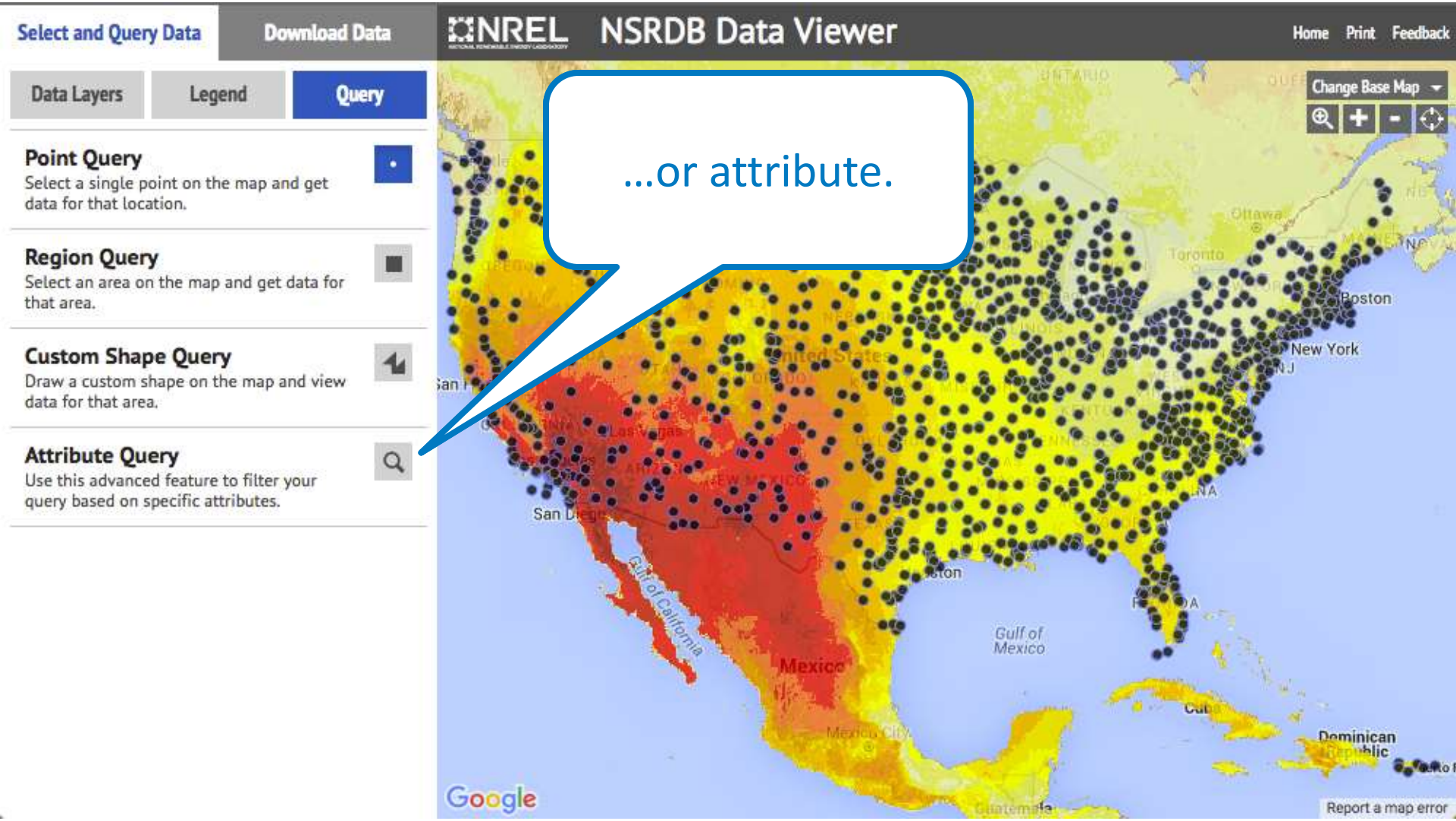


Query Data Layers



Query Data Layers



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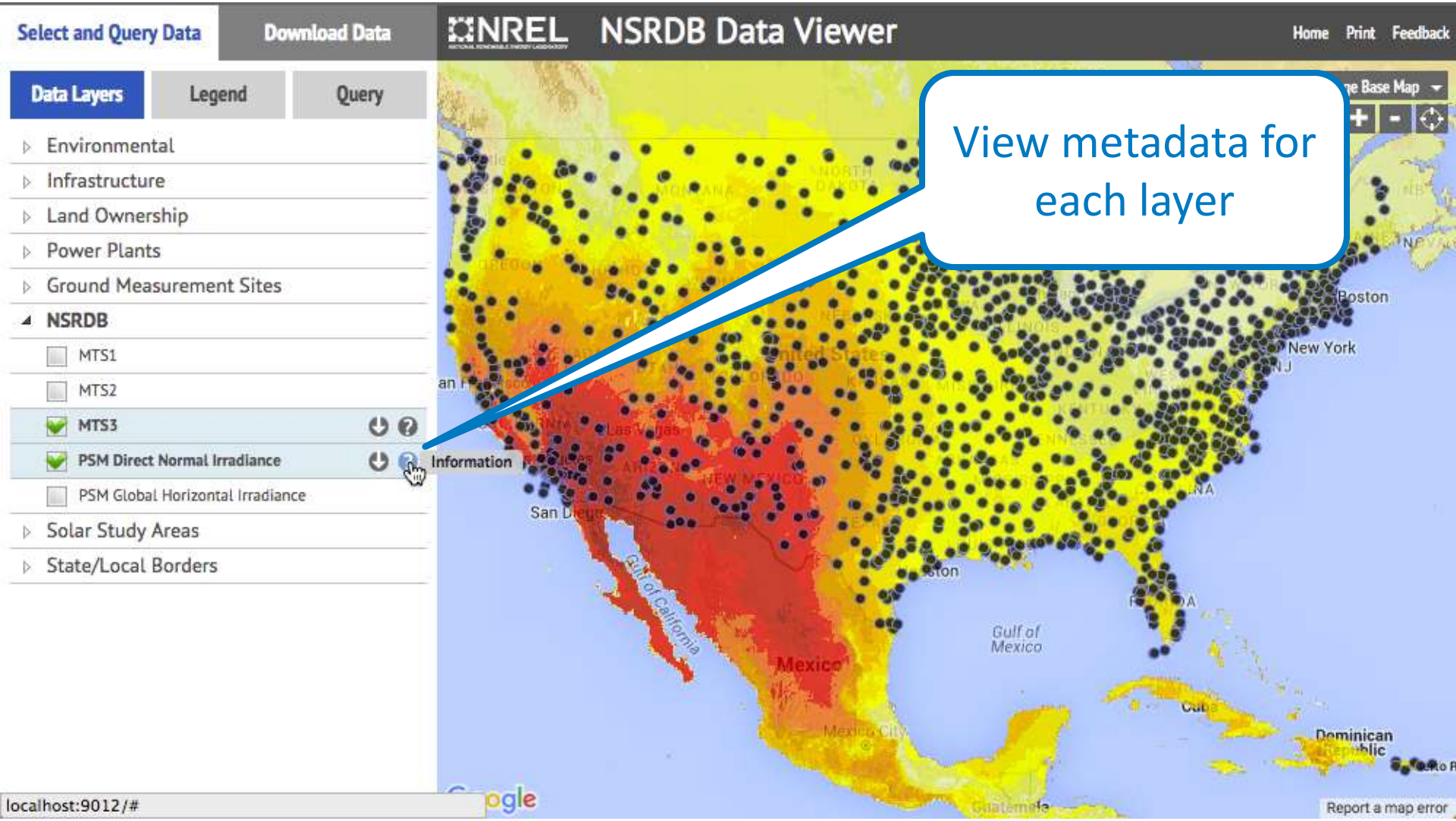

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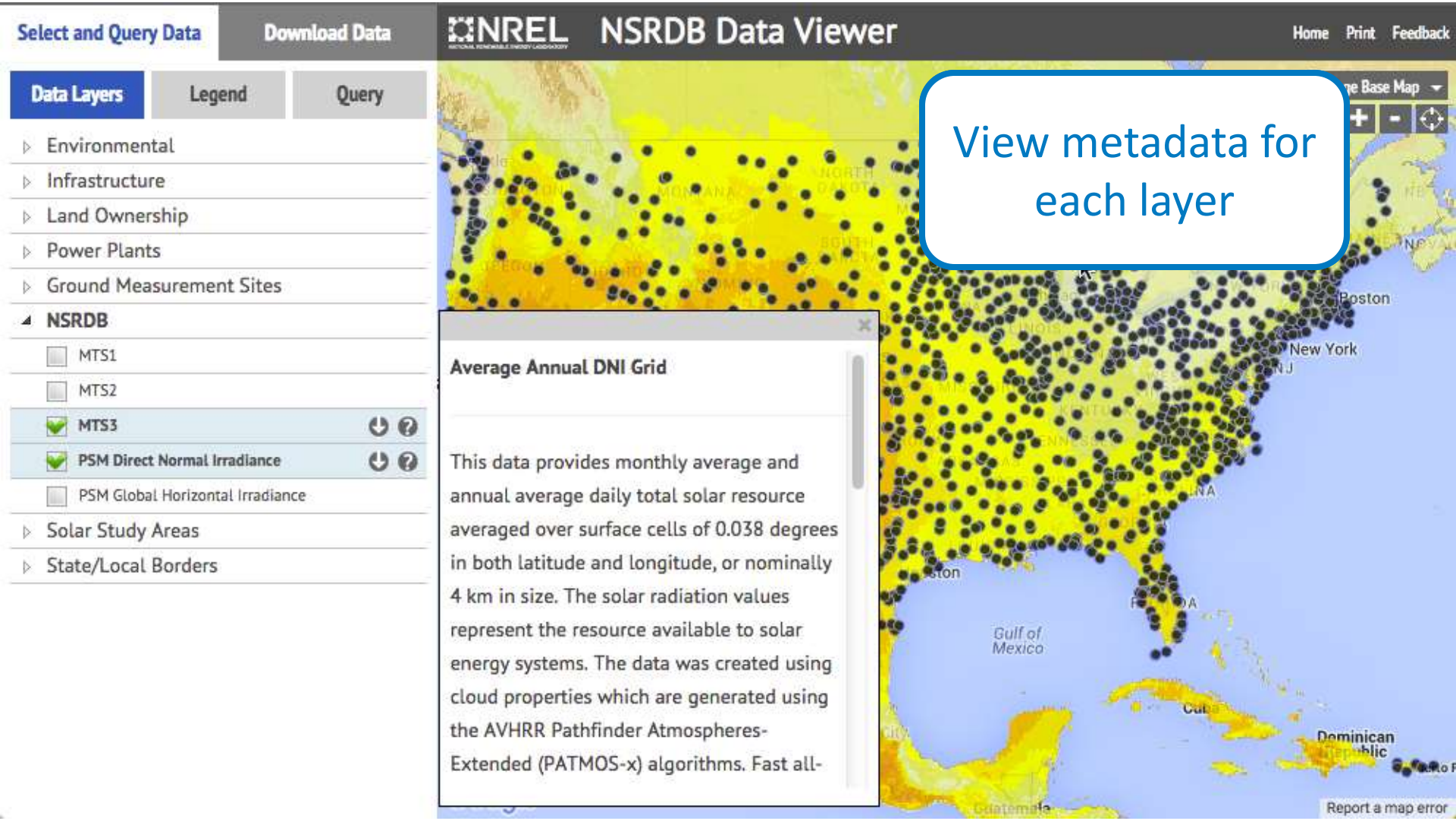
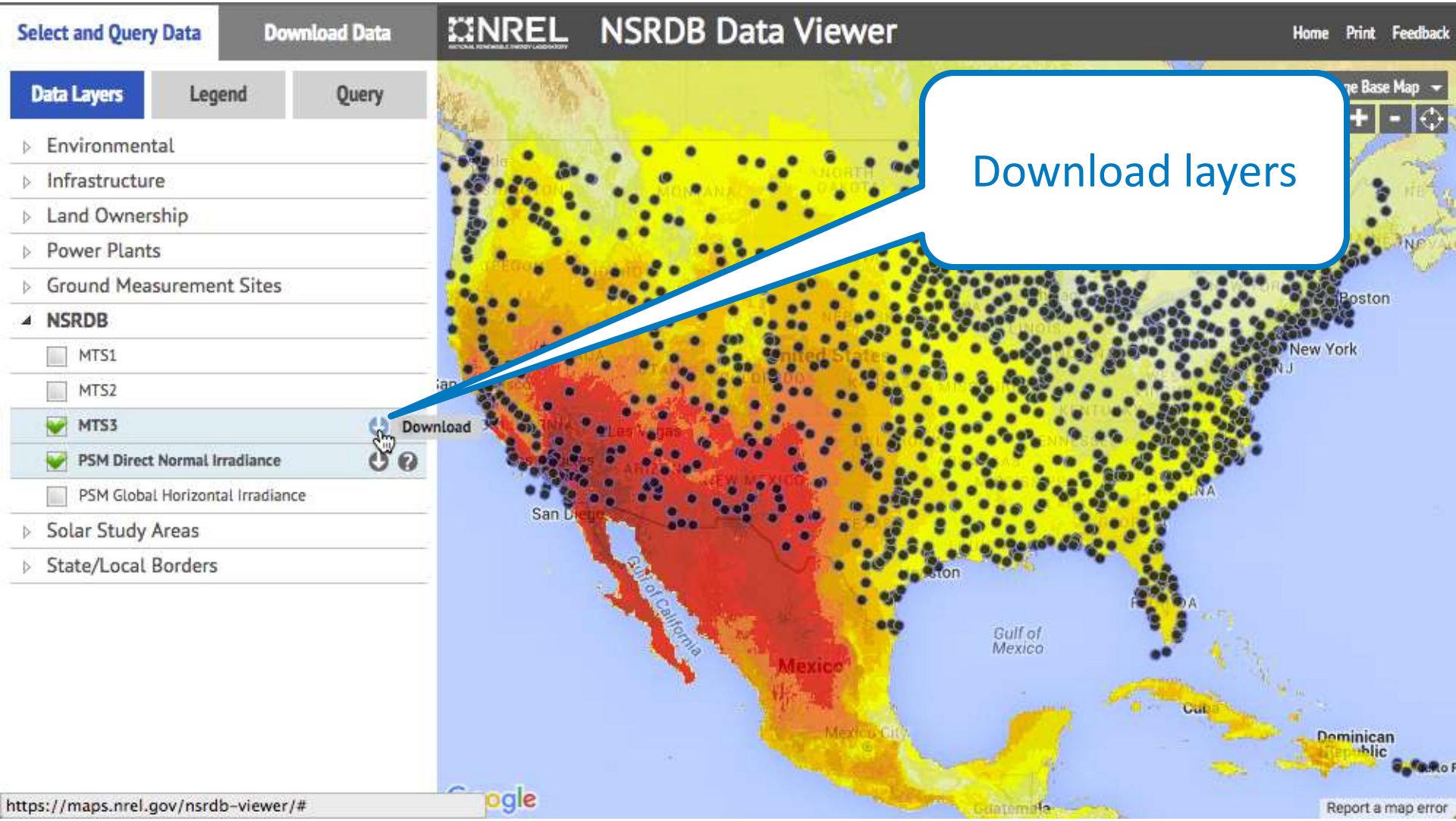
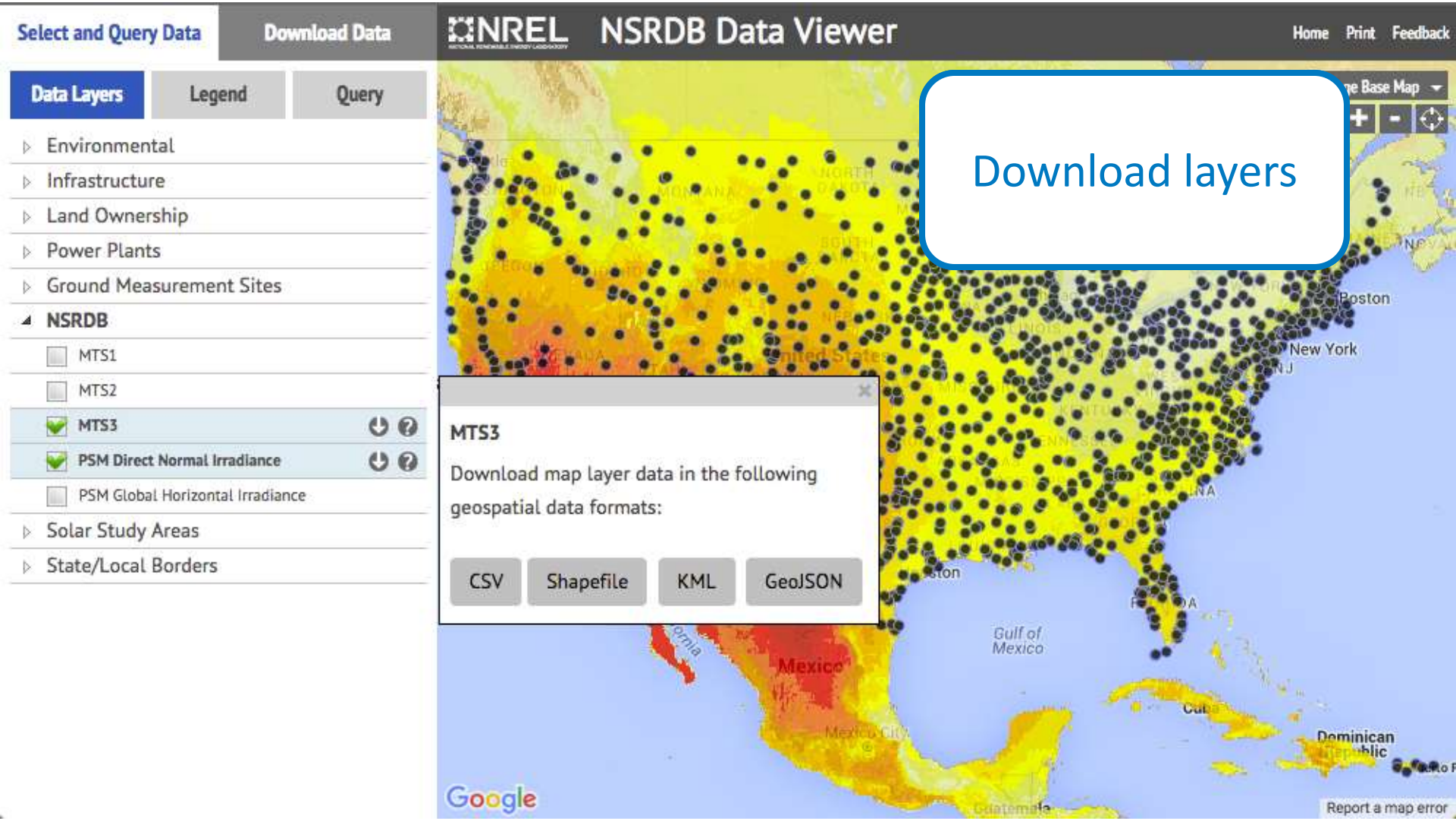


Layer Downloads

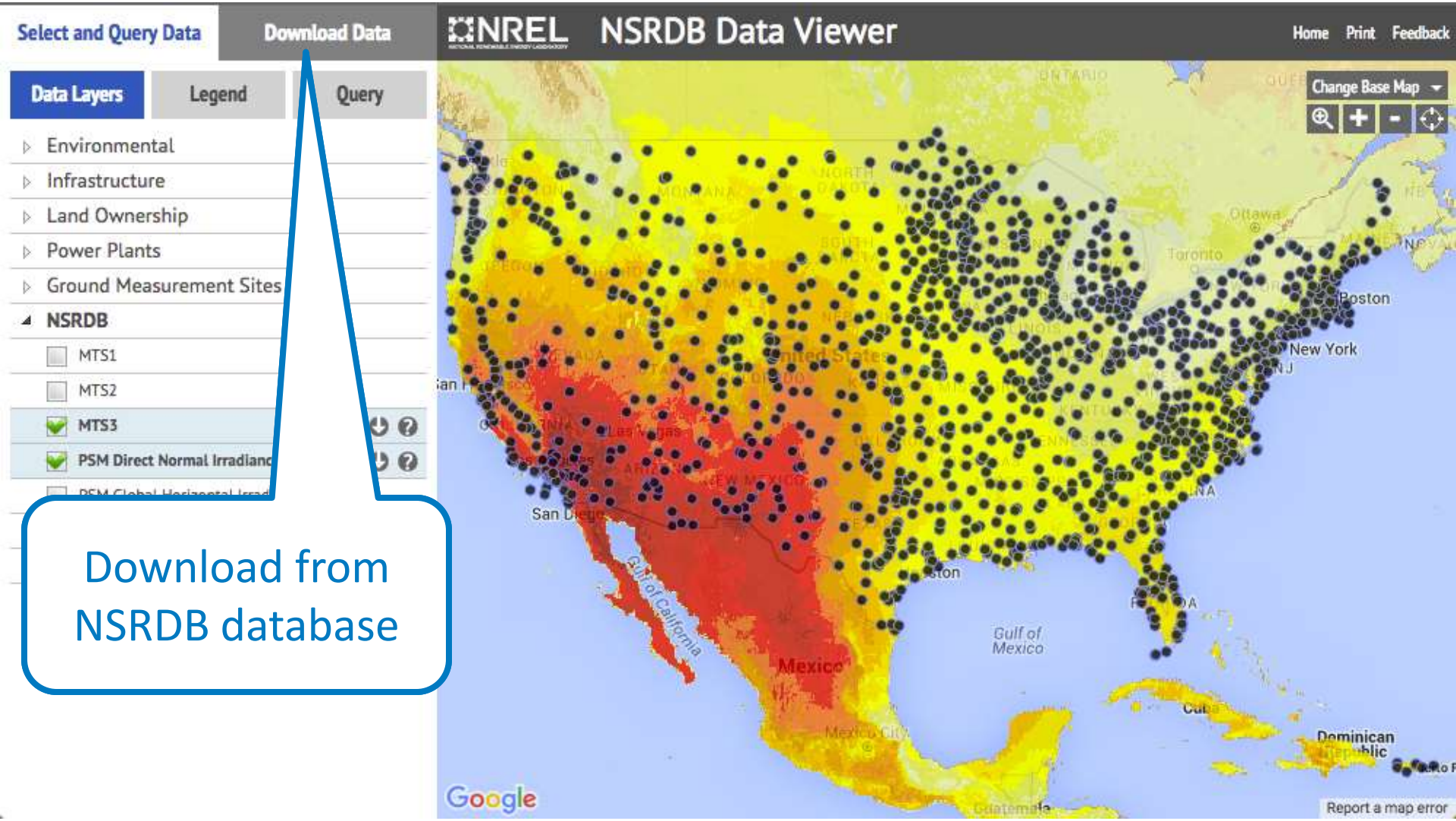


Layer Downloads



NSRDB Data Downloads

NSRDB Data Download



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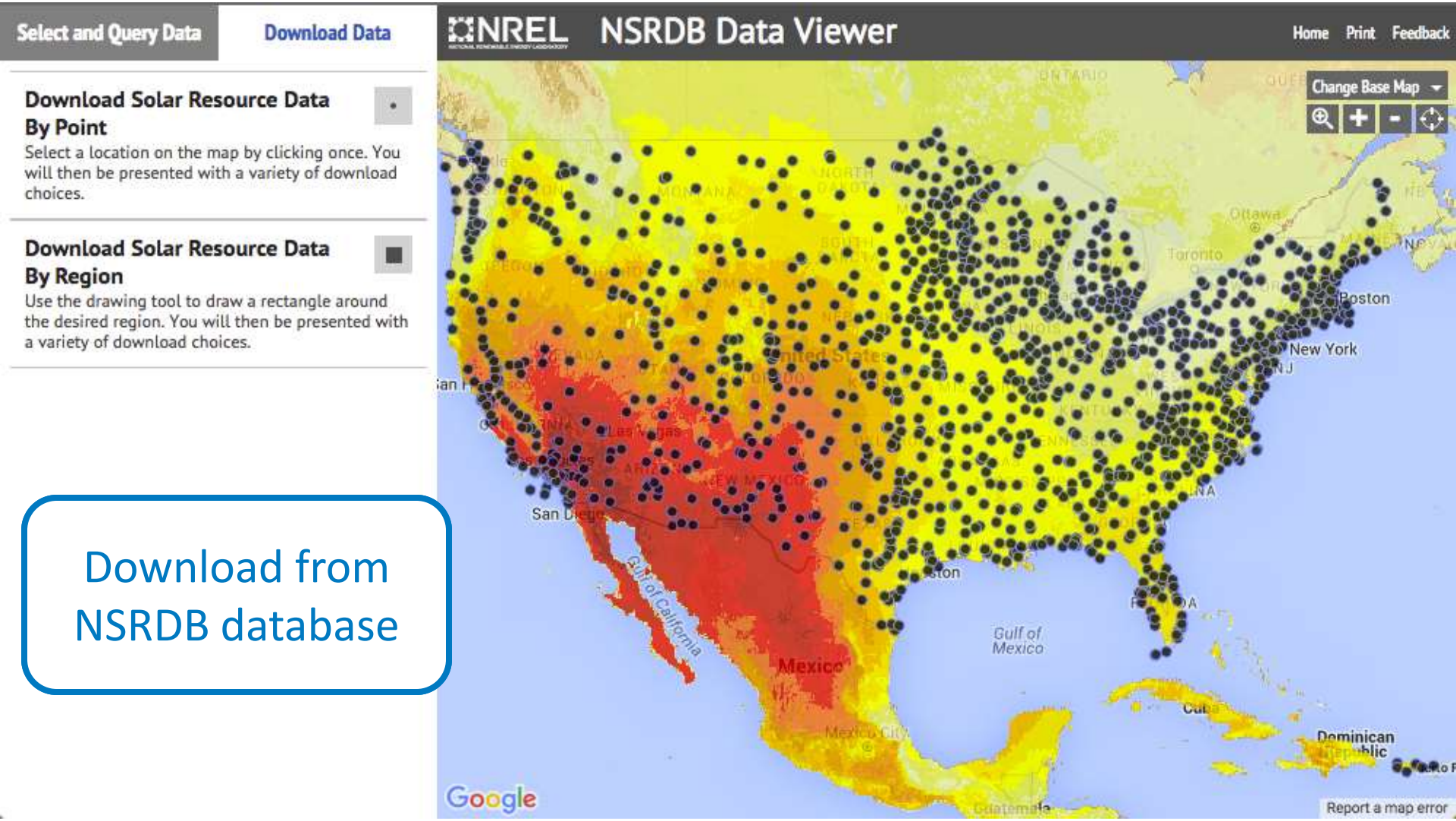
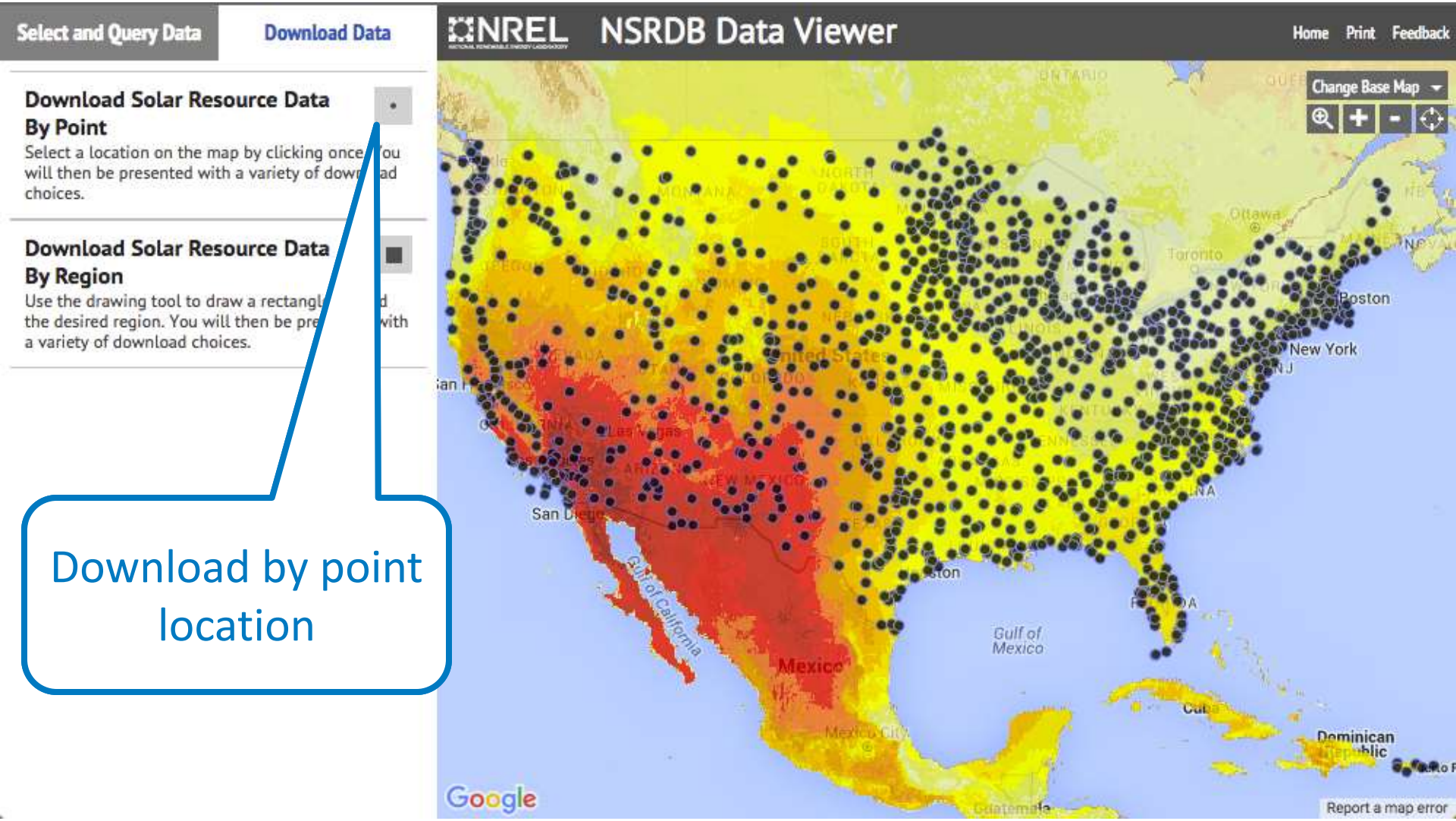


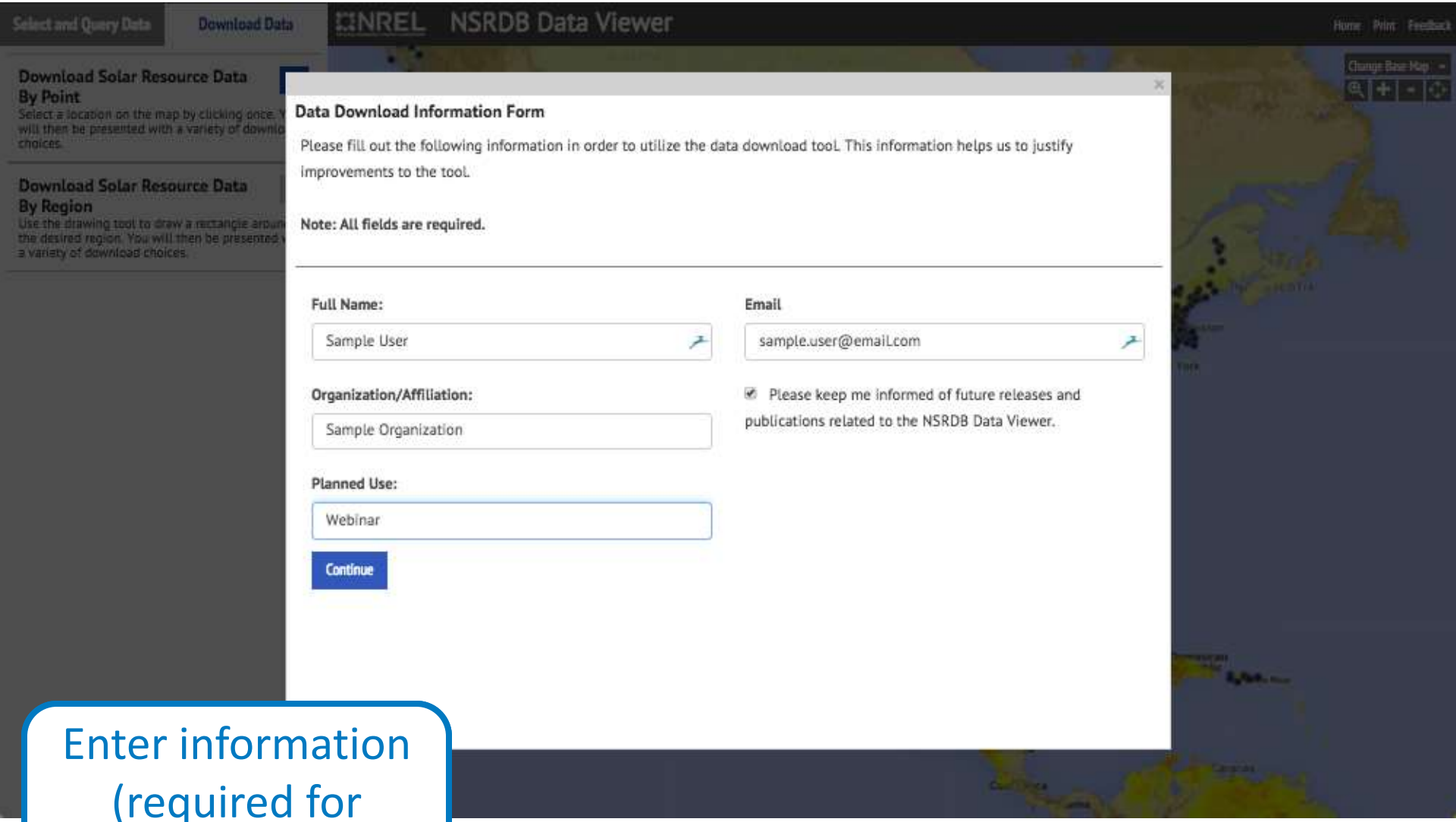
Download from NSRDB database

NSRDB Data Download



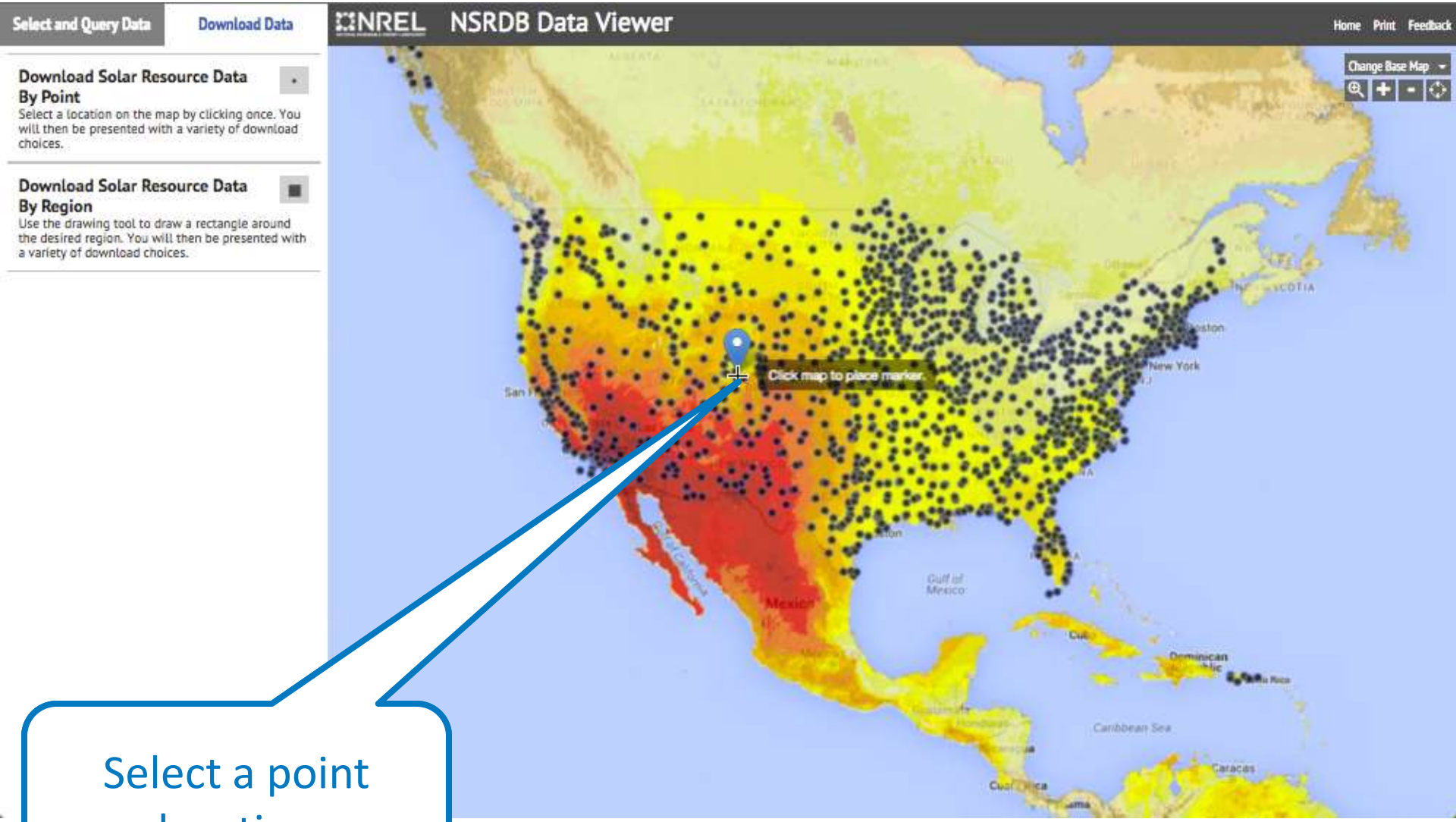
Download by point location

NSRDB Data Download



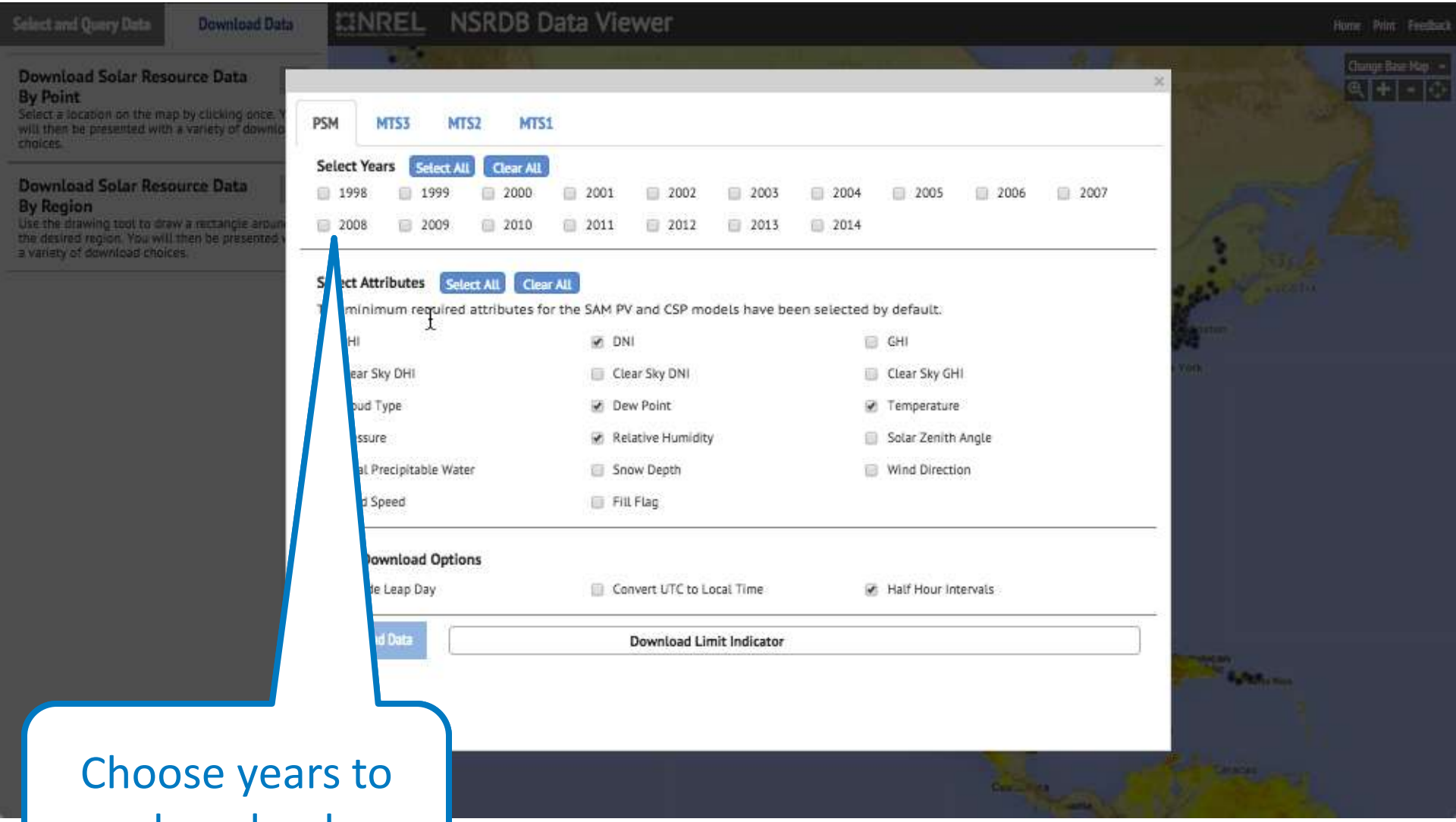
Enter information (required for downloads)

NSRDB Data Download



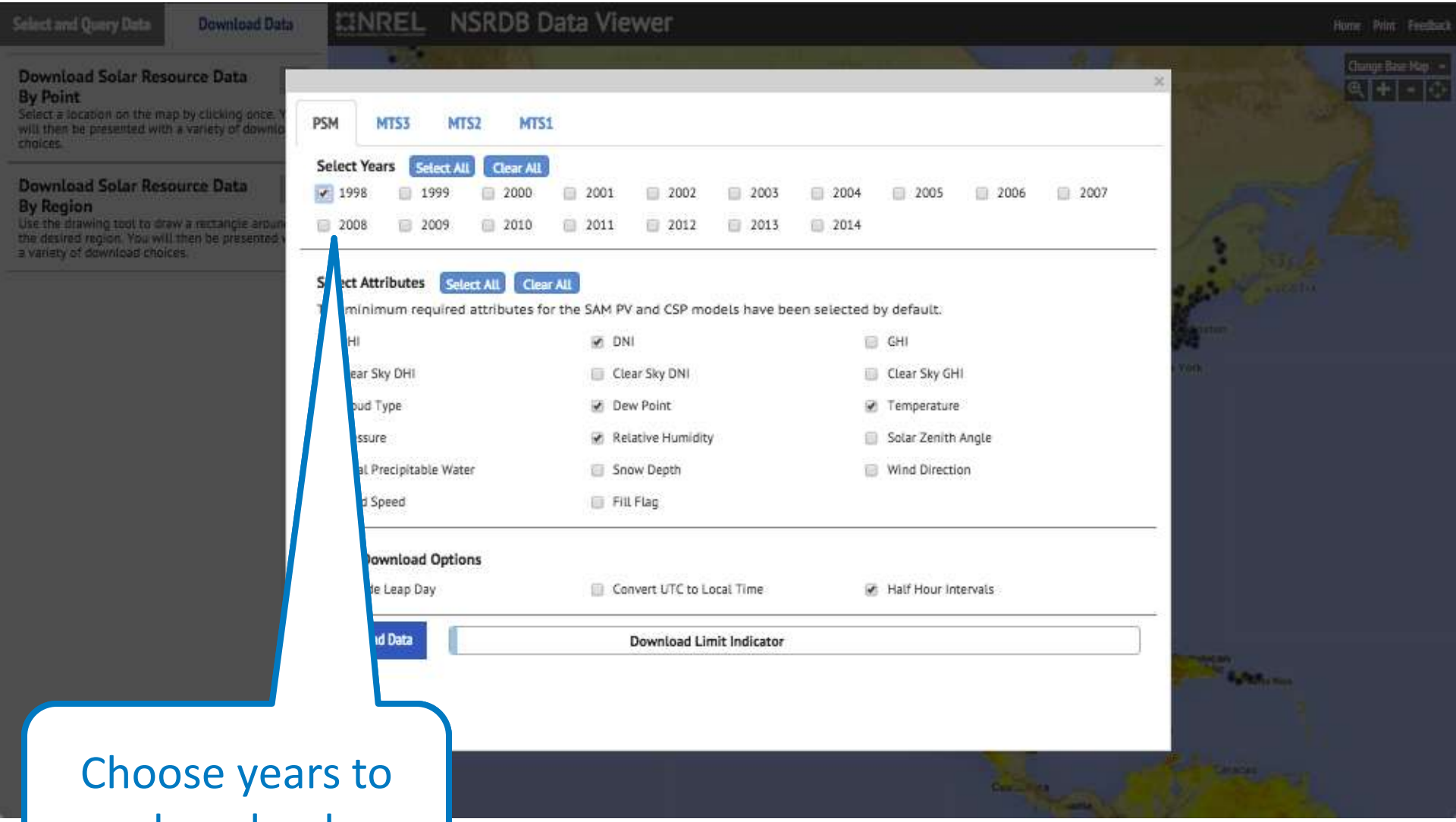
Select a point location

NSRDB Data Download



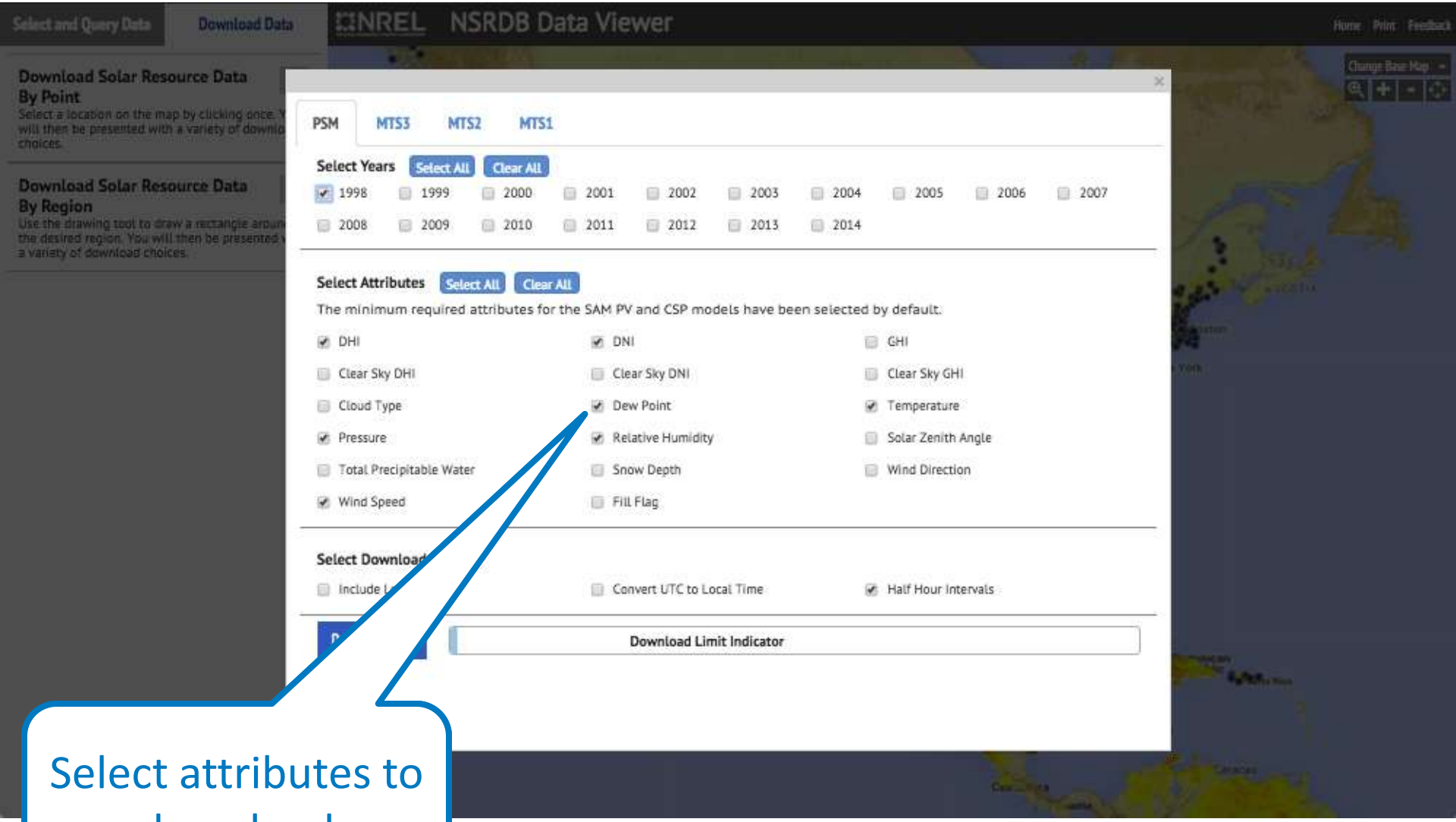
Choose years to download

NSRDB Data Download



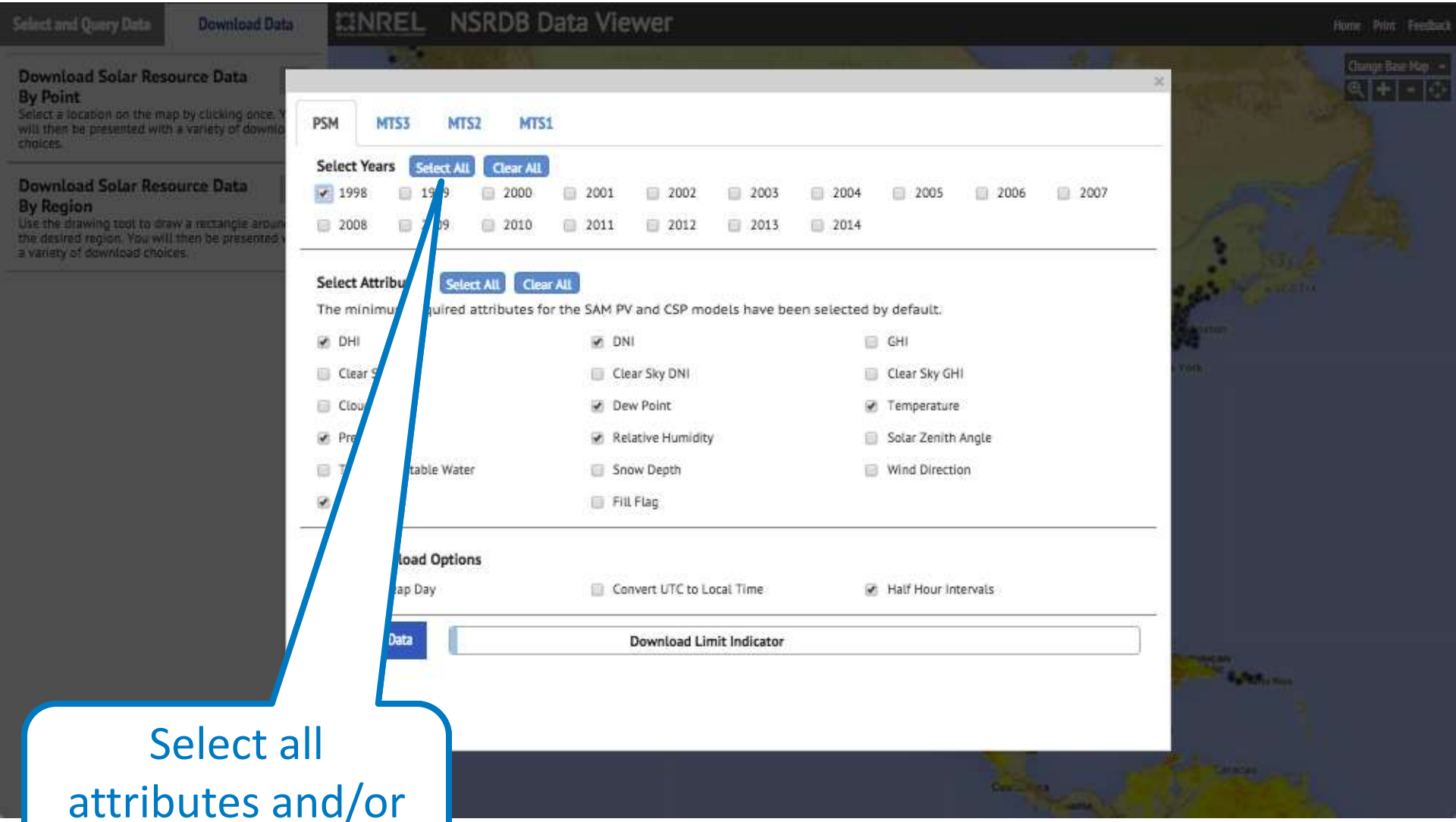
Choose years to download

NSRDB Data Download



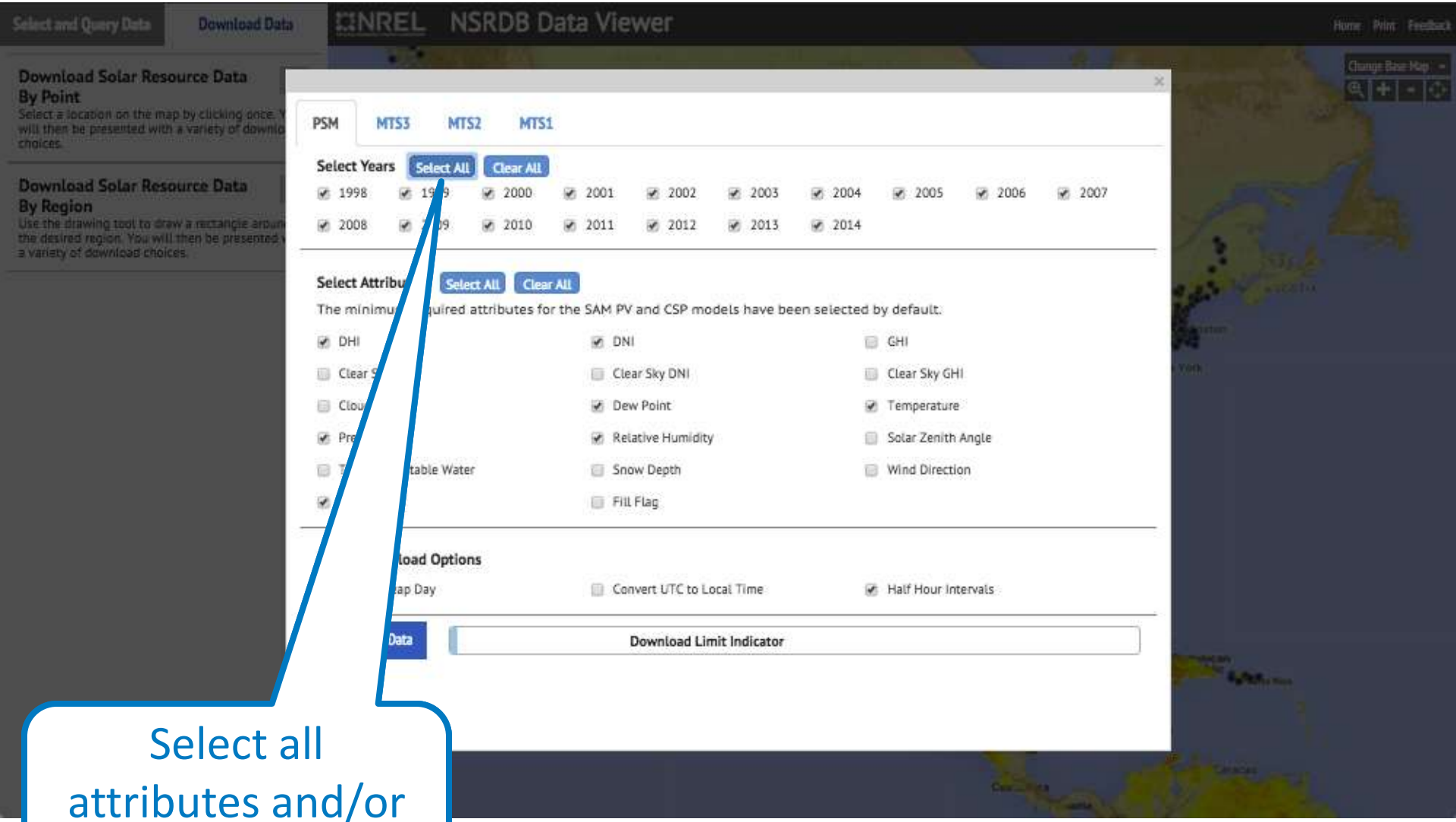
Select attributes to download

NSRDB Data Download



Select all attributes and/or years

NSRDB Data Download



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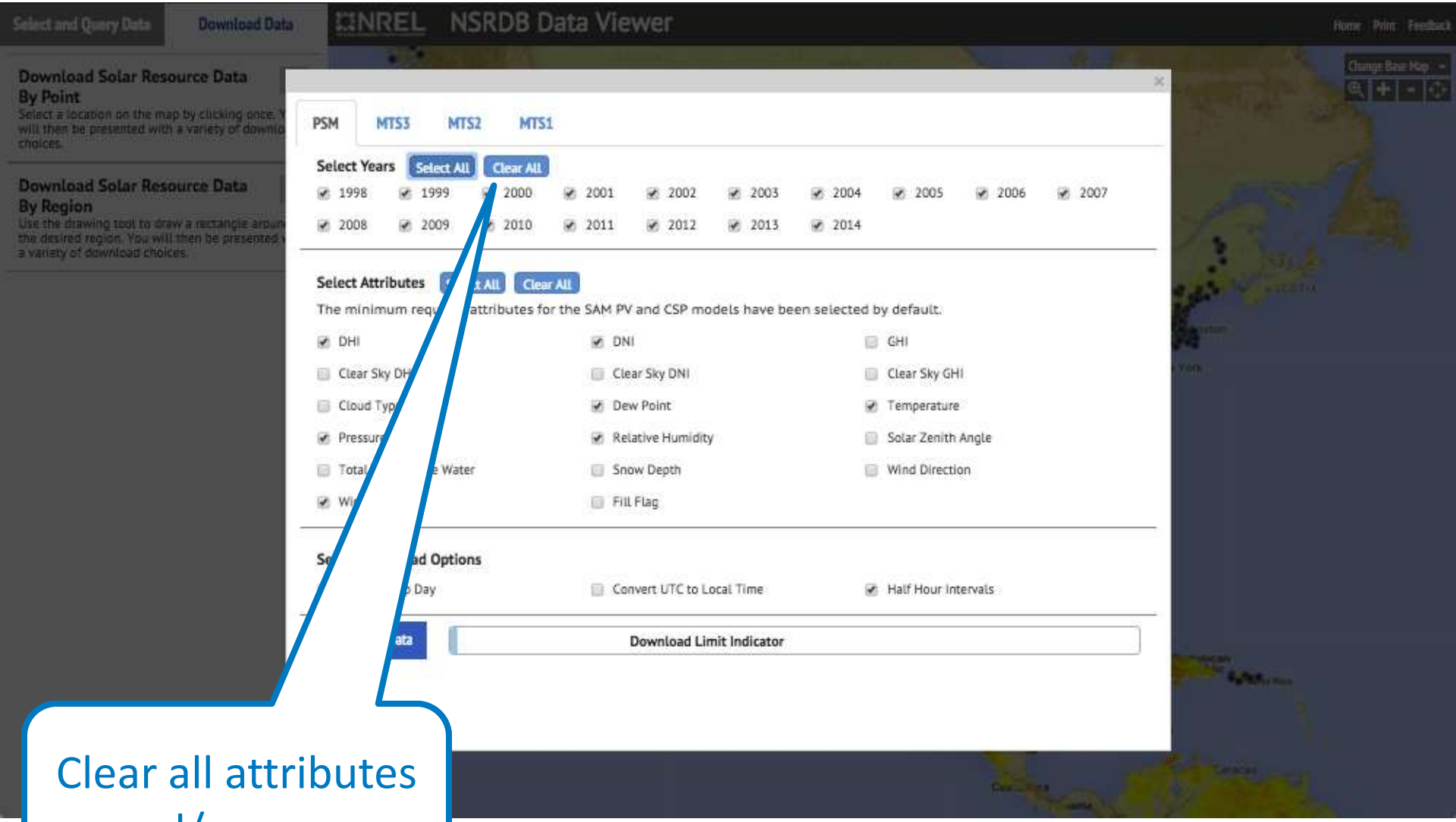

Clear all attributes and/or years

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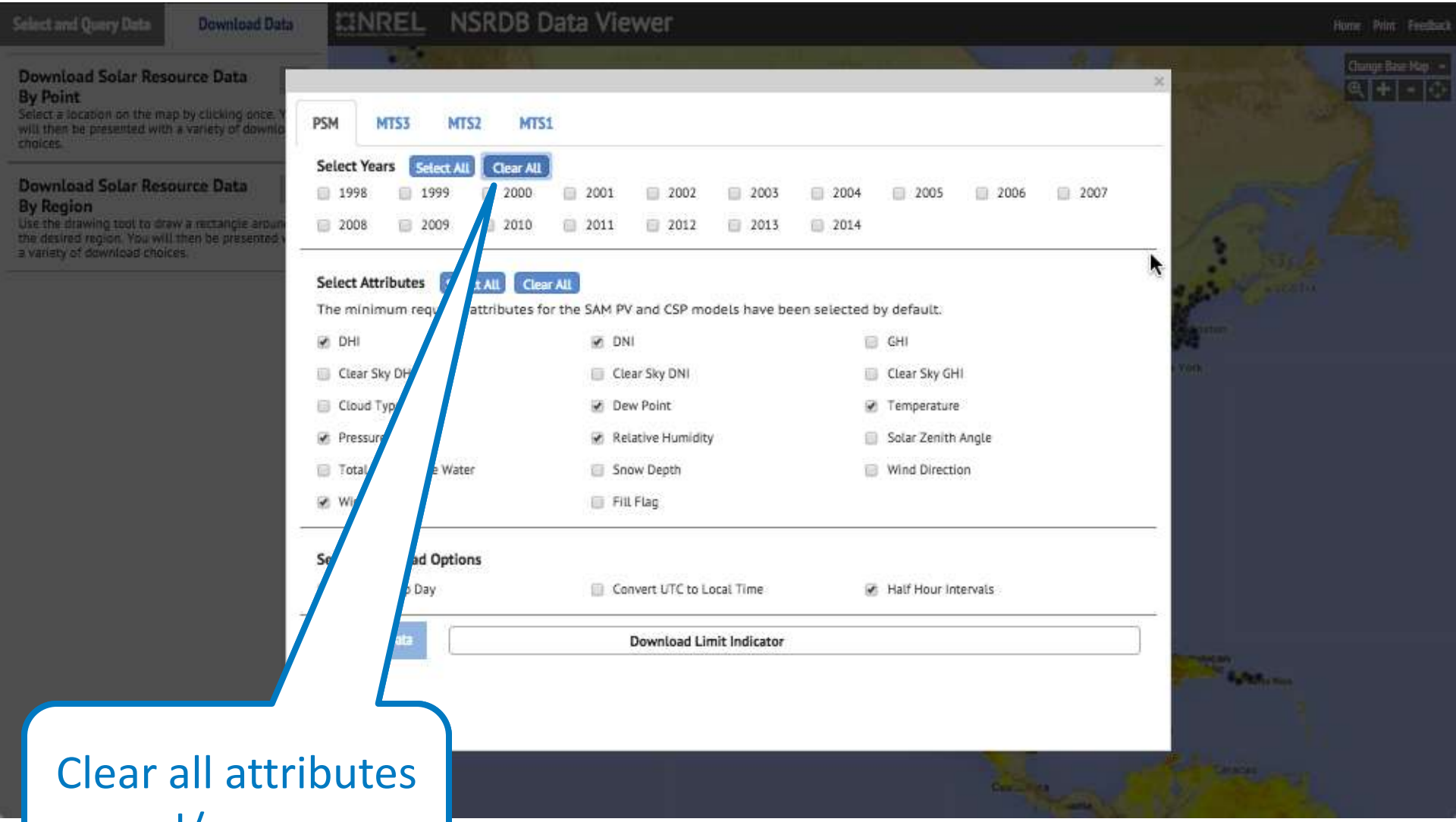

Clear all attributes and/or years

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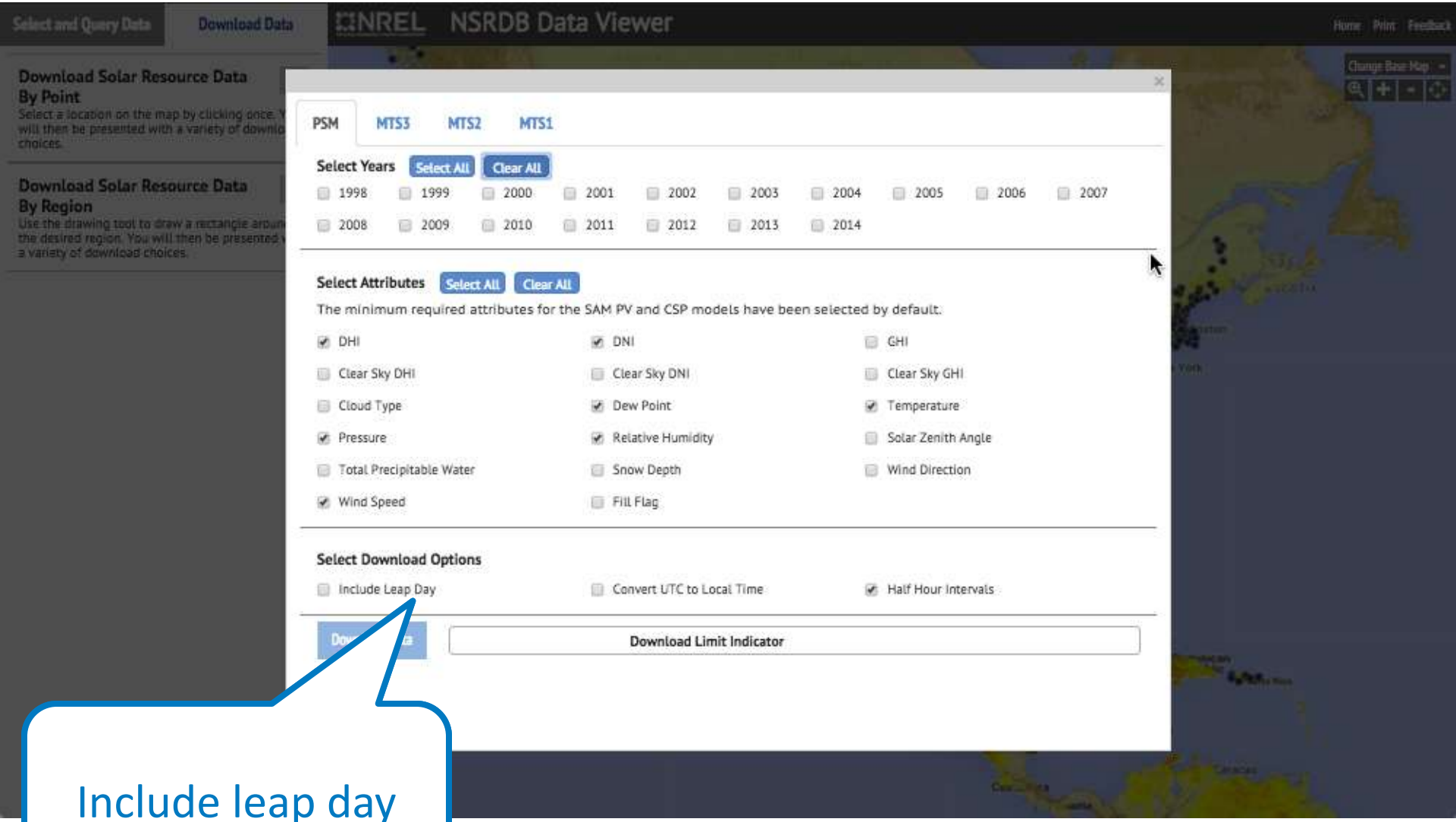
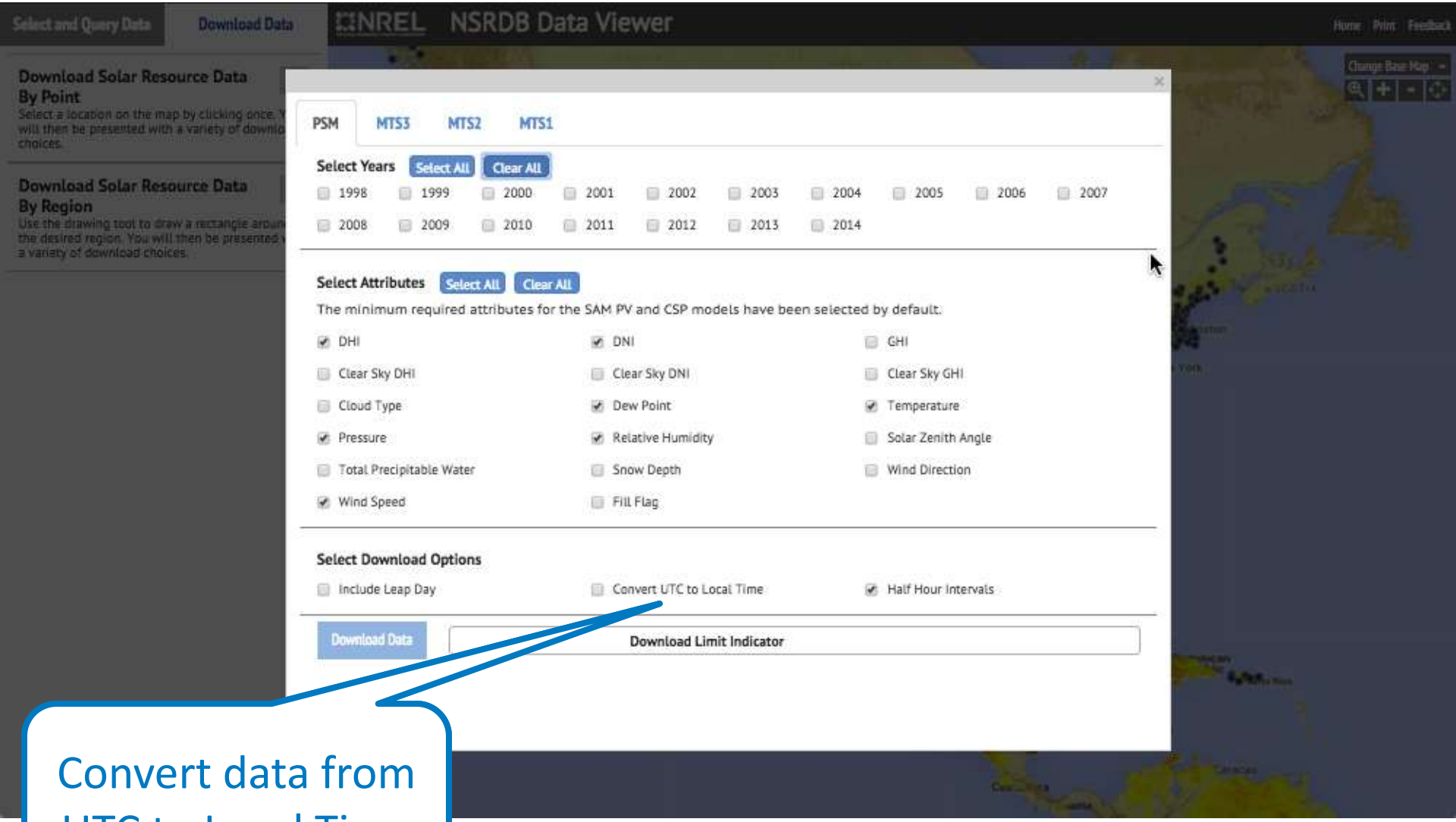


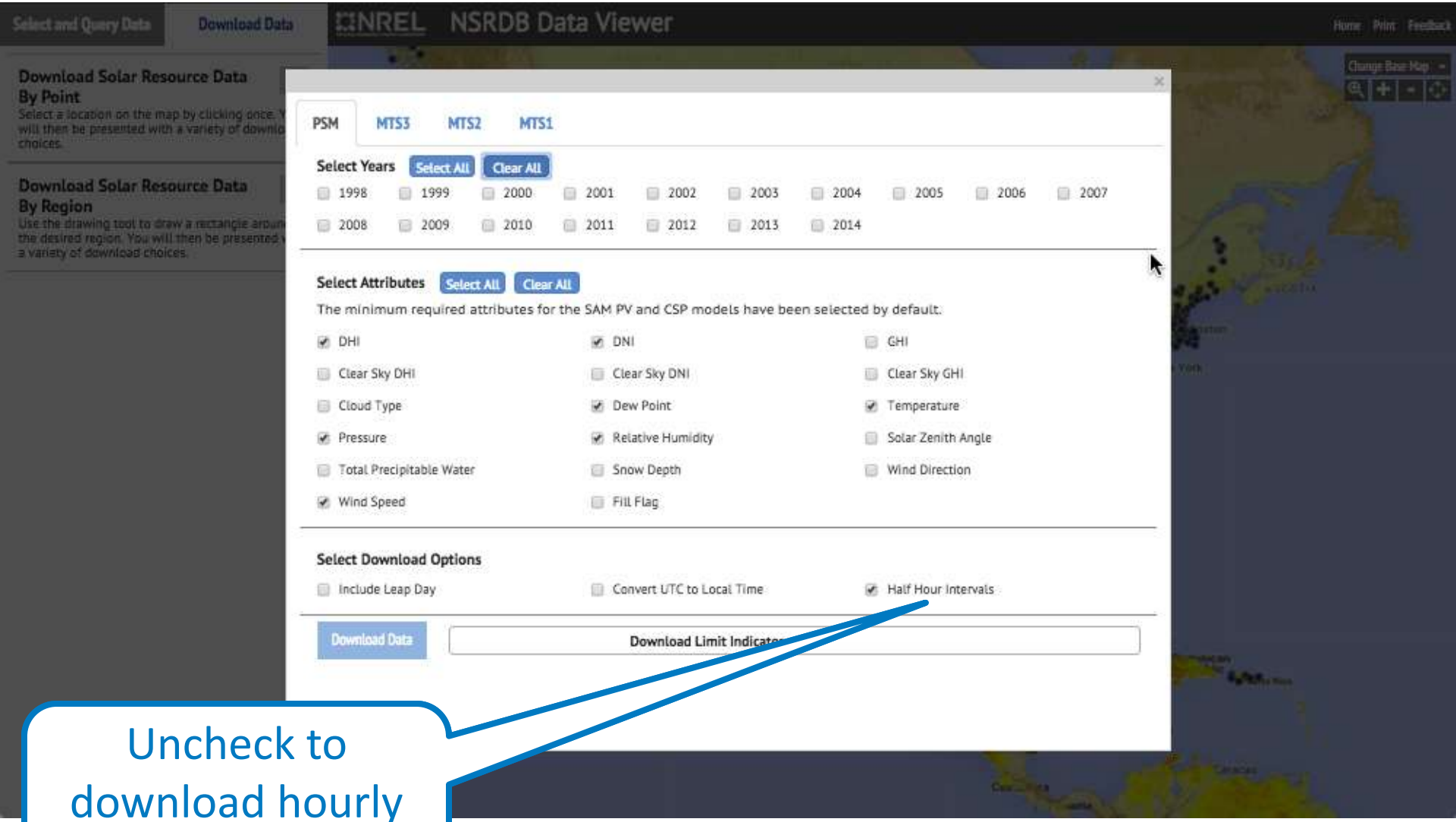
Include leap day

NSRDB Data Download



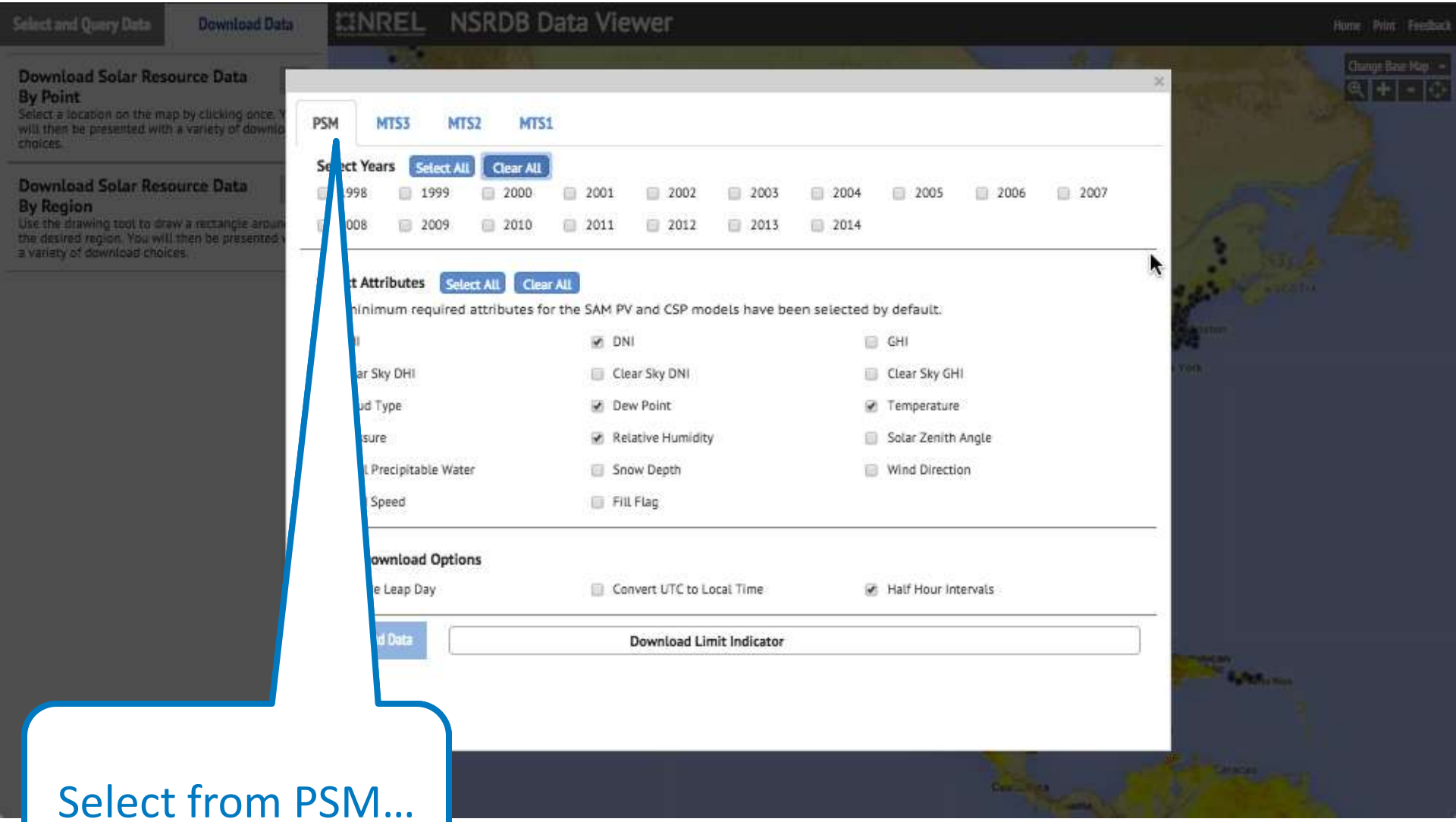
Convert data from UTC to Local Time

NSRDB Data Download



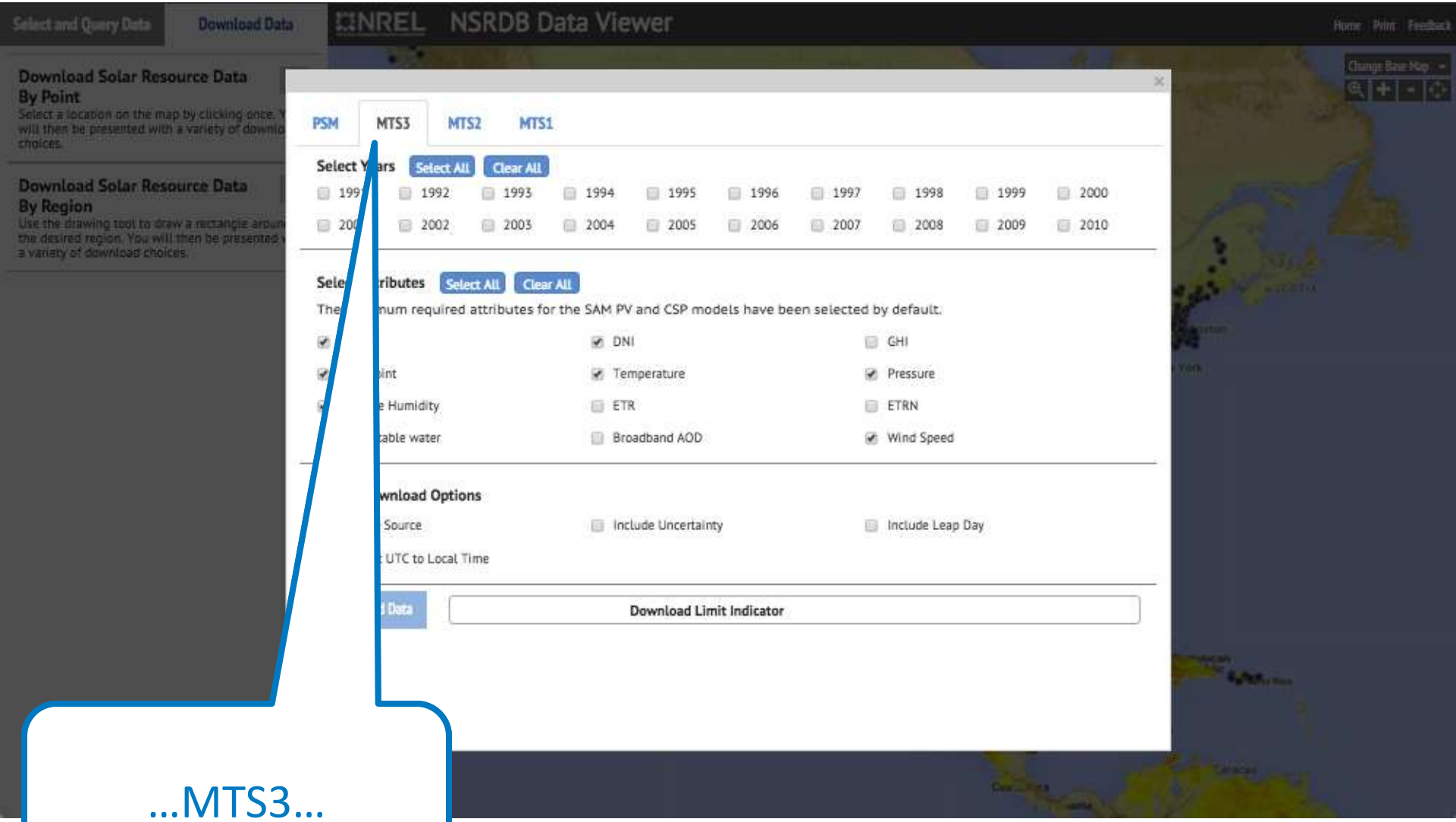
Uncheck to download hourly data

NSRDB Data Download



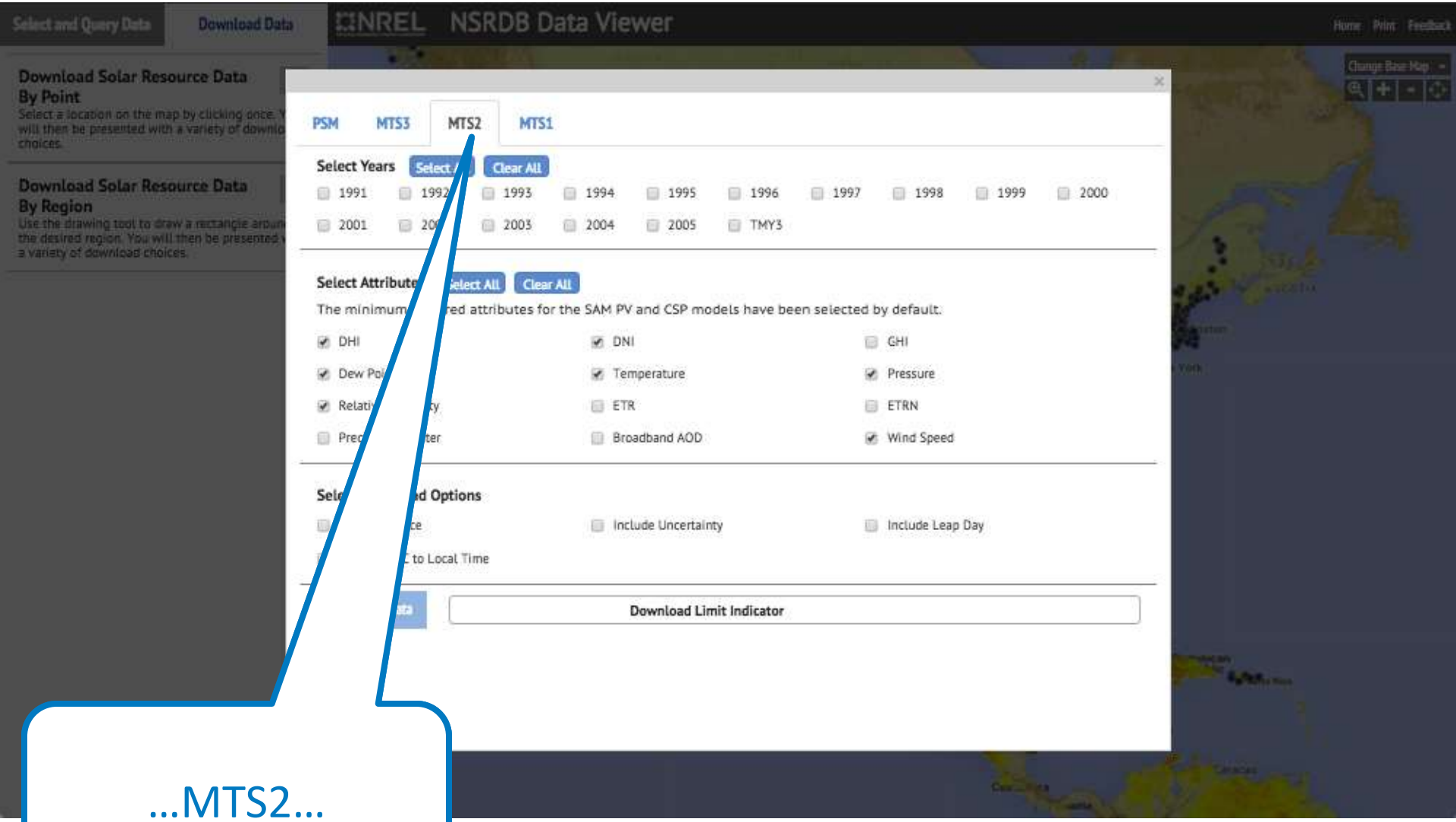
Select from PSM…

NSRDB Data Download



…MTS3…

NSRDB Data Download



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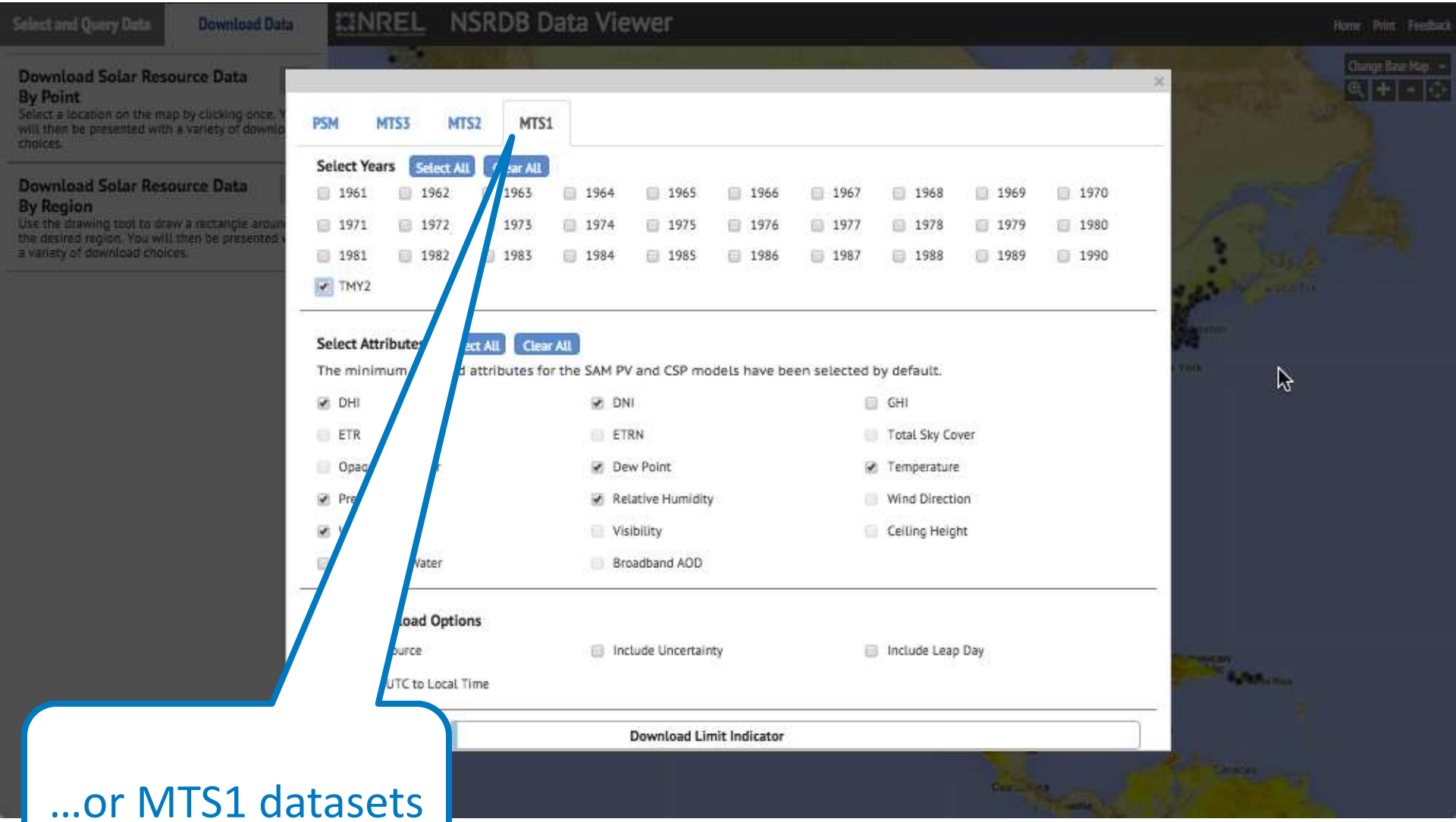
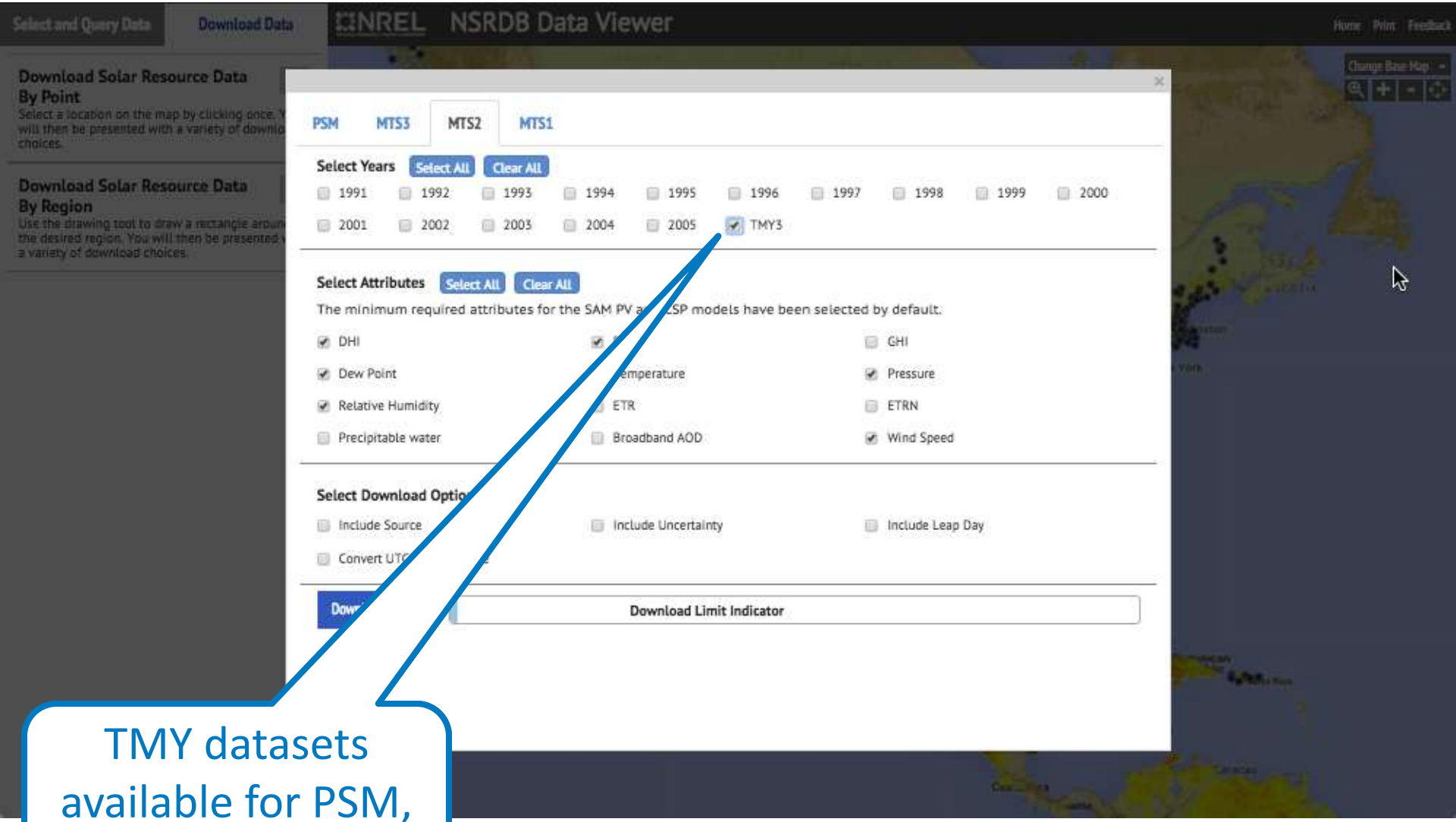


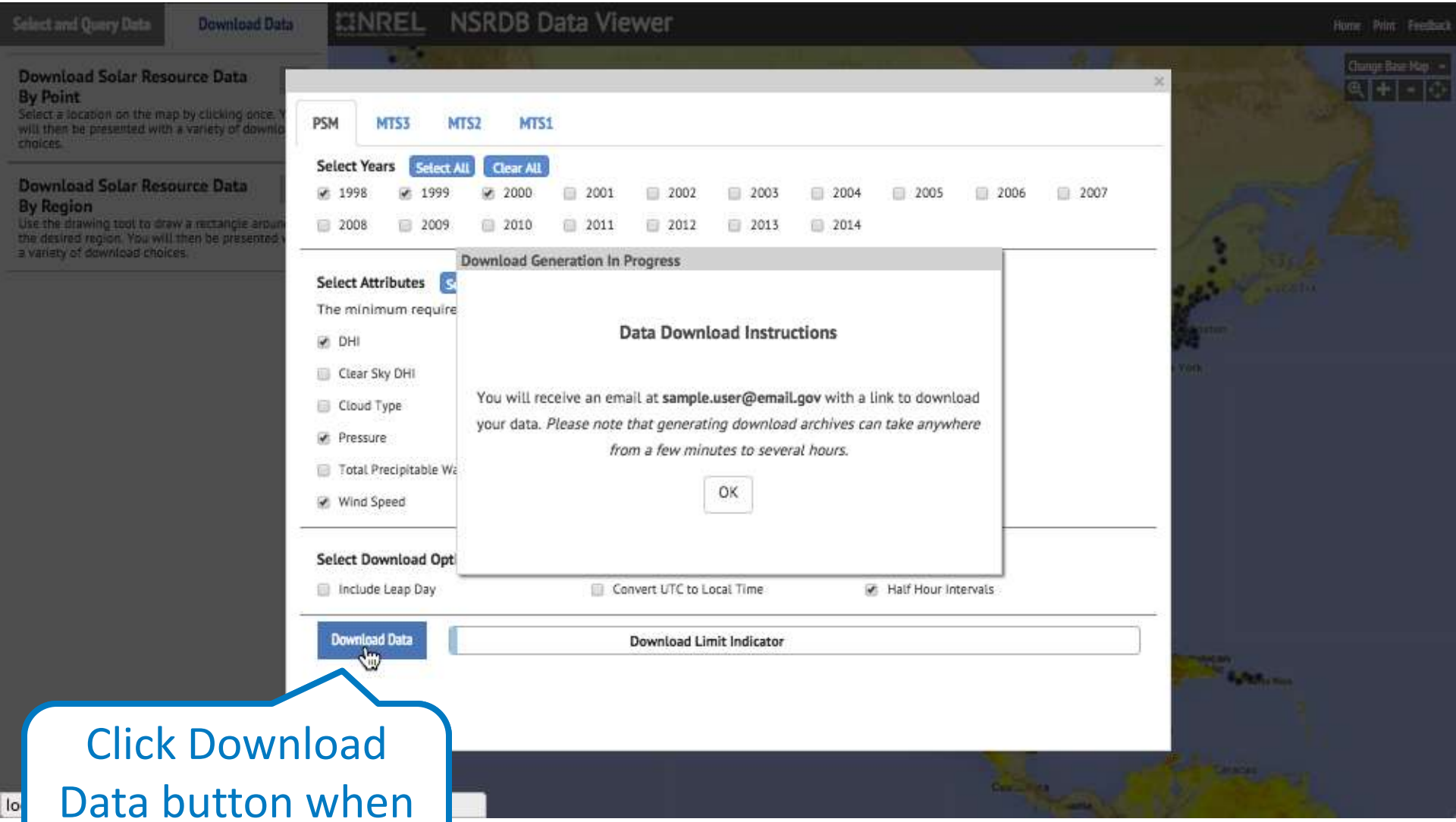
…or MTS1 datasets

NSRDB Data Download



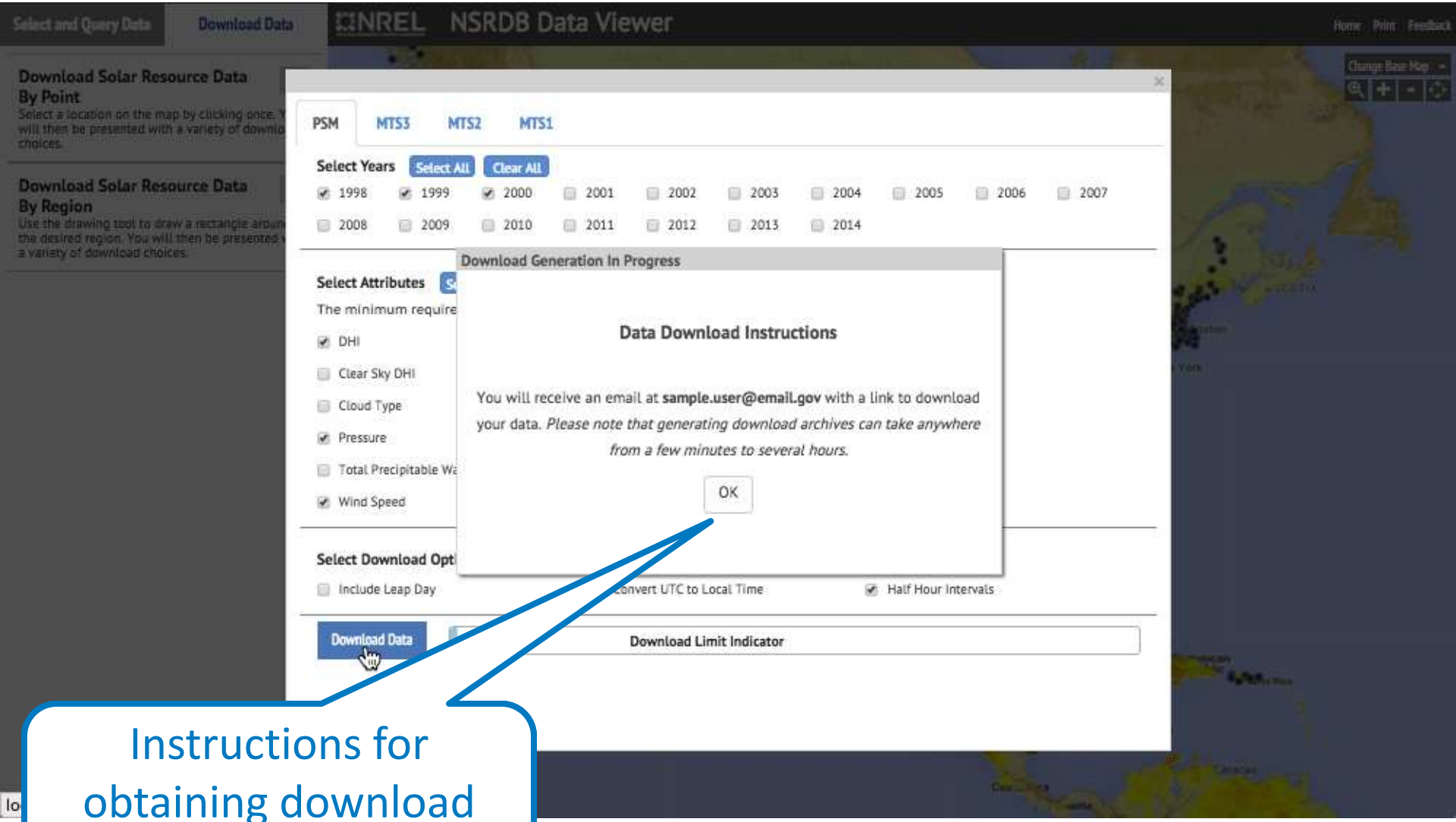
TMY datasets available for PSM, MTS1, & MTS2

NSRDB Data Download



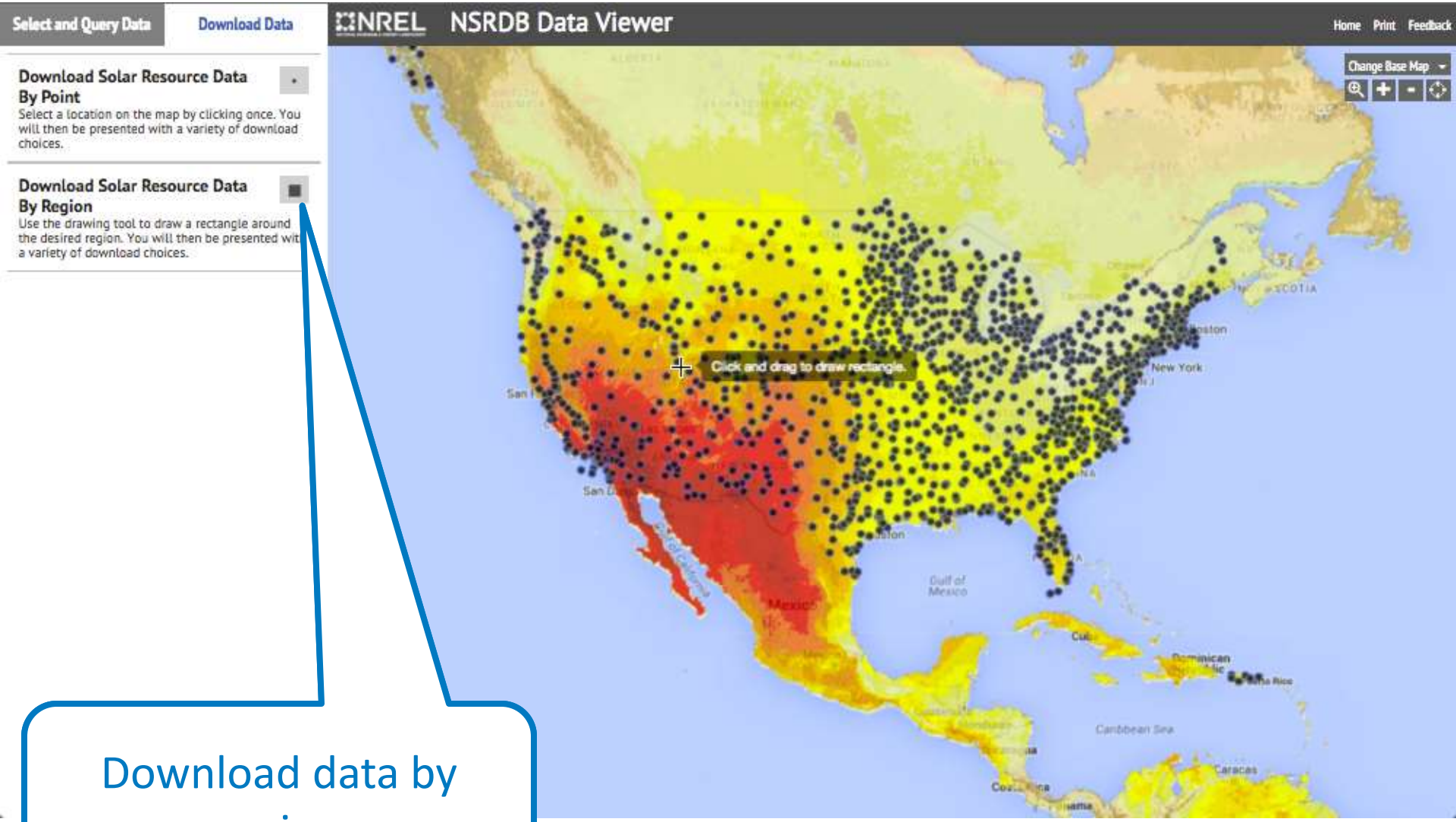
Click Download Data button when ready

NSRDB Data Download



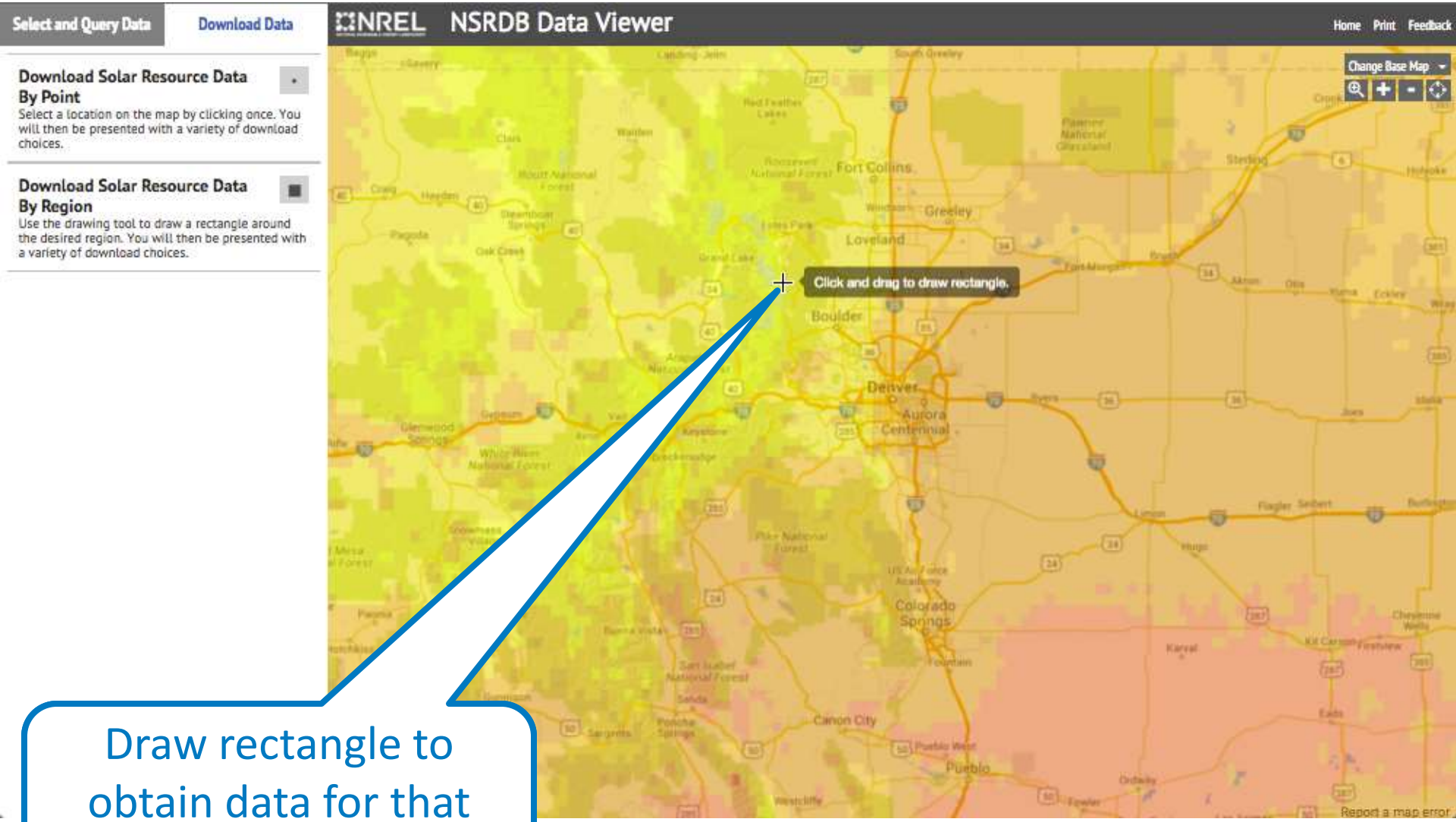
Instructions for obtaining download will be emailed

NSRDB Data Download



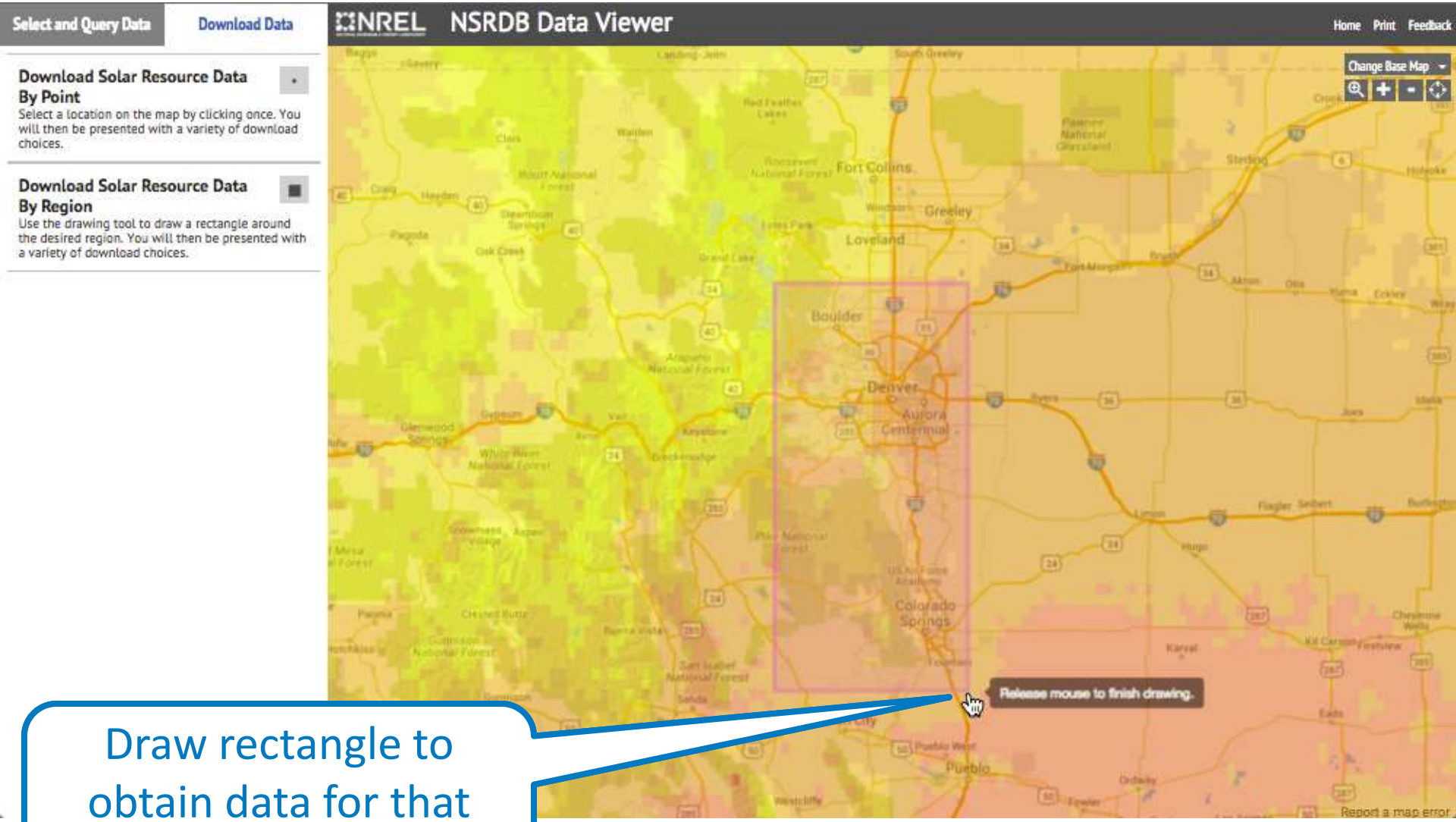
Download data by region

NSRDB Data Download



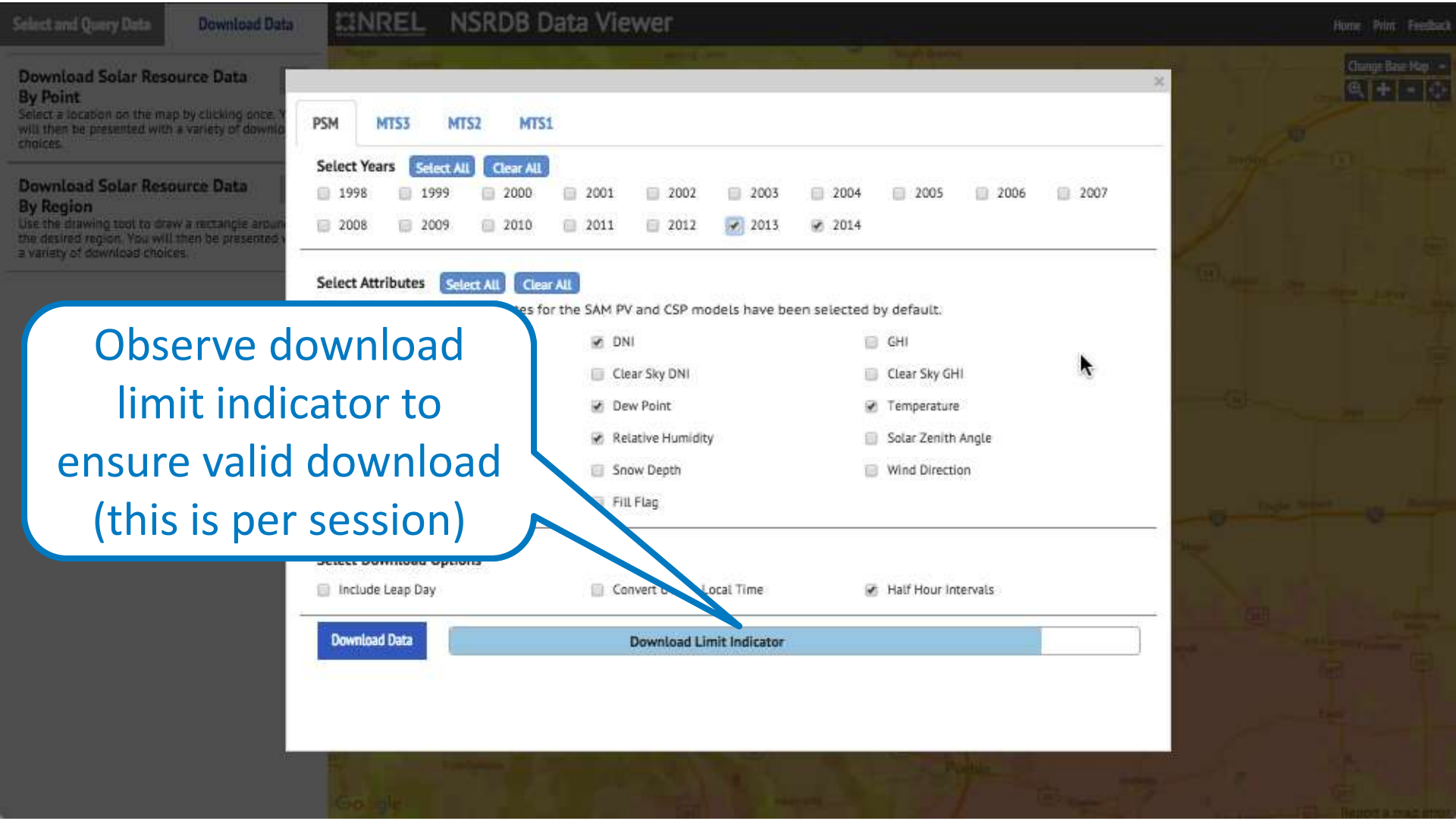
Draw rectangle to obtain data for that region

NSRDB Data Download



Draw rectangle to obtain data for that region

NSRDB Data Download



NSRDB Data Download

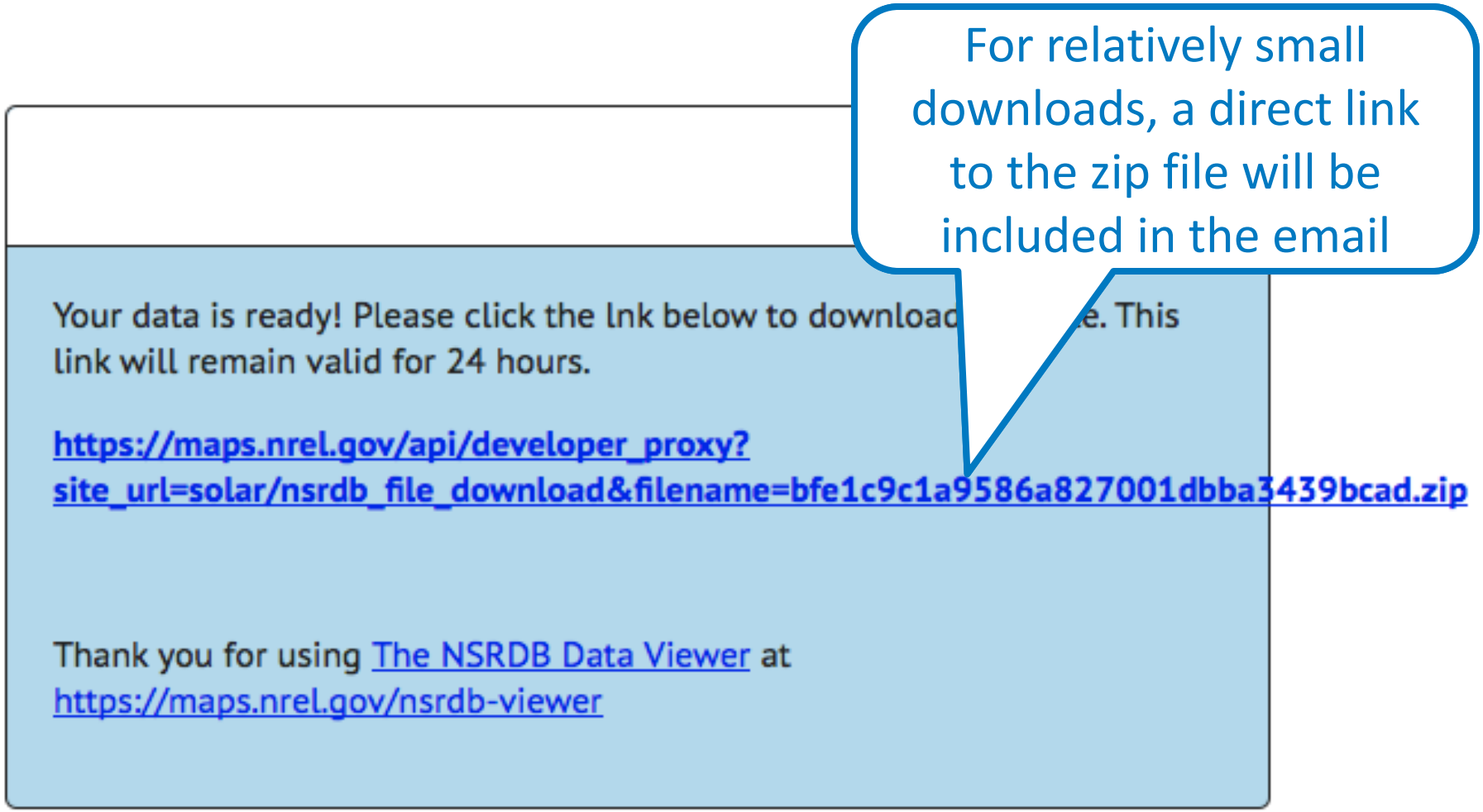
Wait for email with download instructions

Your data is ready! Please click the lnk below to download your file. This link will remain valid for 24 hours.

https://maps.nrel.gov/api/developer_proxy?site_url=solar/nsrdb_file_download&filename=bfe1c9c1a9586a827001dbba3439bcad.zip

Thank you for using The NSRDB Data Viewer at https://maps.nrel.gov/nsrdb-viewer

NSRDB Data Download



NSRDB Data Download

Larger downloads use the Globus service. Follow the instructions in the link to set up an account.

Your data is ready! The file is named **2015-11-30_15:42:21/9aa67fe001a132e6aee08396673d…zip**. This file will be available for 24 hours.

For full instructions on completing your download via Globus Connect, please view the page at: https://nsrdb.nrel.gov/nsrdb-viewer

Thank you for using The NSRDB Data Viewer at https://maps.nrel.gov/nsrdb-viewer

NSRDB Data Download

Follow this link to sign up for a Globus account

Globus Data Download Instructions

STEP 1

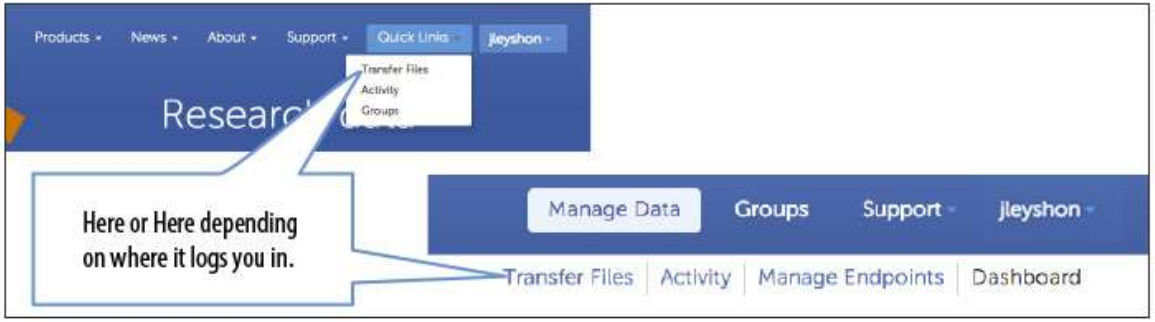
- Sign up for a Globus account at https://www.globus.org/SignUp. The email verification link will likely open a new browser window from your inbox and log you into Globus.

STEP 2

- If the verification does not log you in, sign in at https://www.globus.org/.

STEP 3

- Go to "Transfer Files."



STEP 4

- Set up a Globus Connect Personal Endpoint.

NOTE:

NSRDB Data Download

Globus Data Download Instructions

STEP 1

- Sign up for a Globus account at https://www.globus.org/SignUp. The email verification link will likely open a new browser window from your inbox and log you into Globus.

STEP 2

- If the verification does not log you in, sign in at https://www.globus.org/.

STEP 3

- Go to "Transfer Files."

Once your account has been created, sign in to your account

- Set up a Globus Connect Personal Endpoint.

NOTE:

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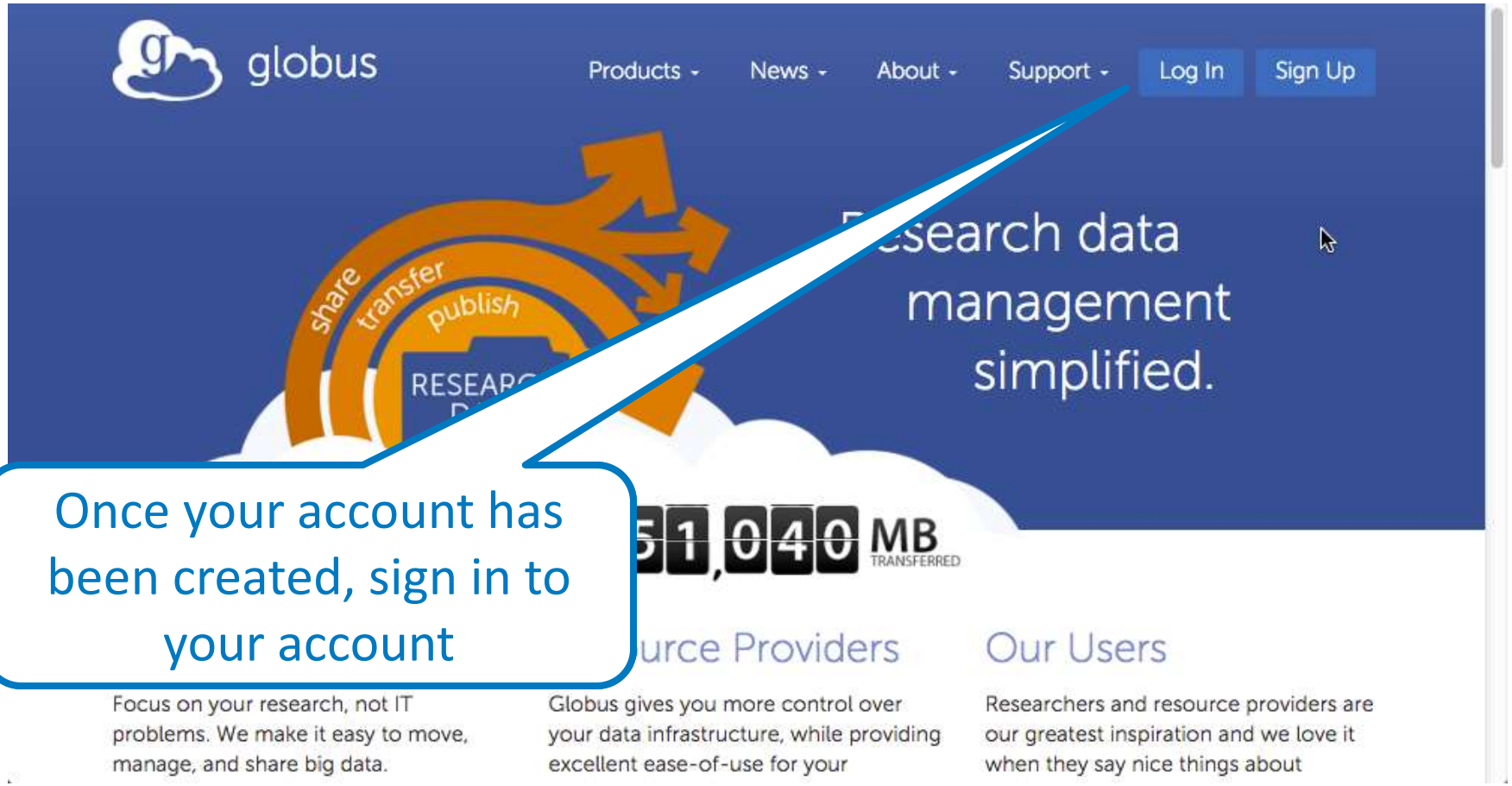
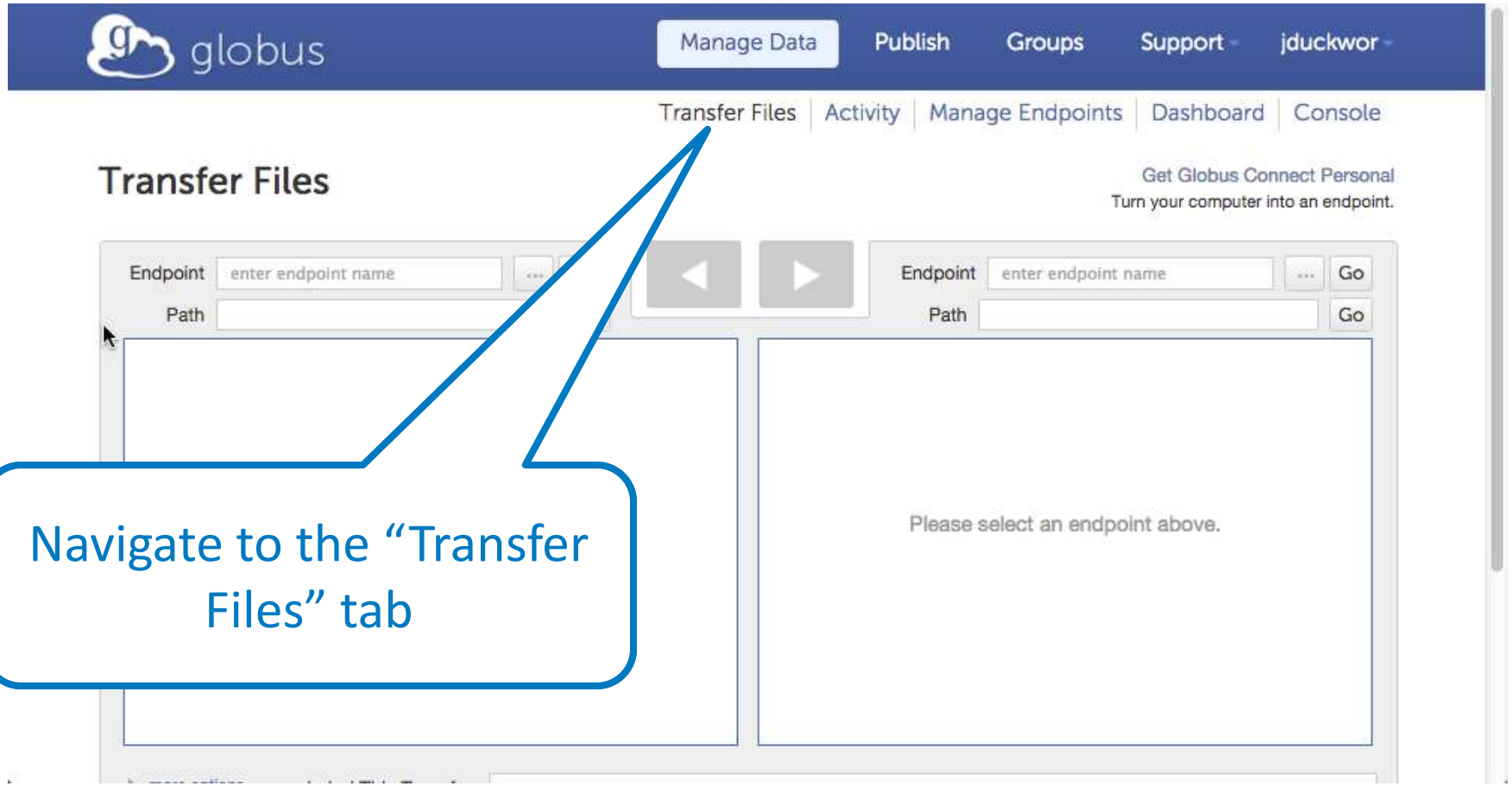


Once your account has been created, sign in to your account

NSRDB Data Download



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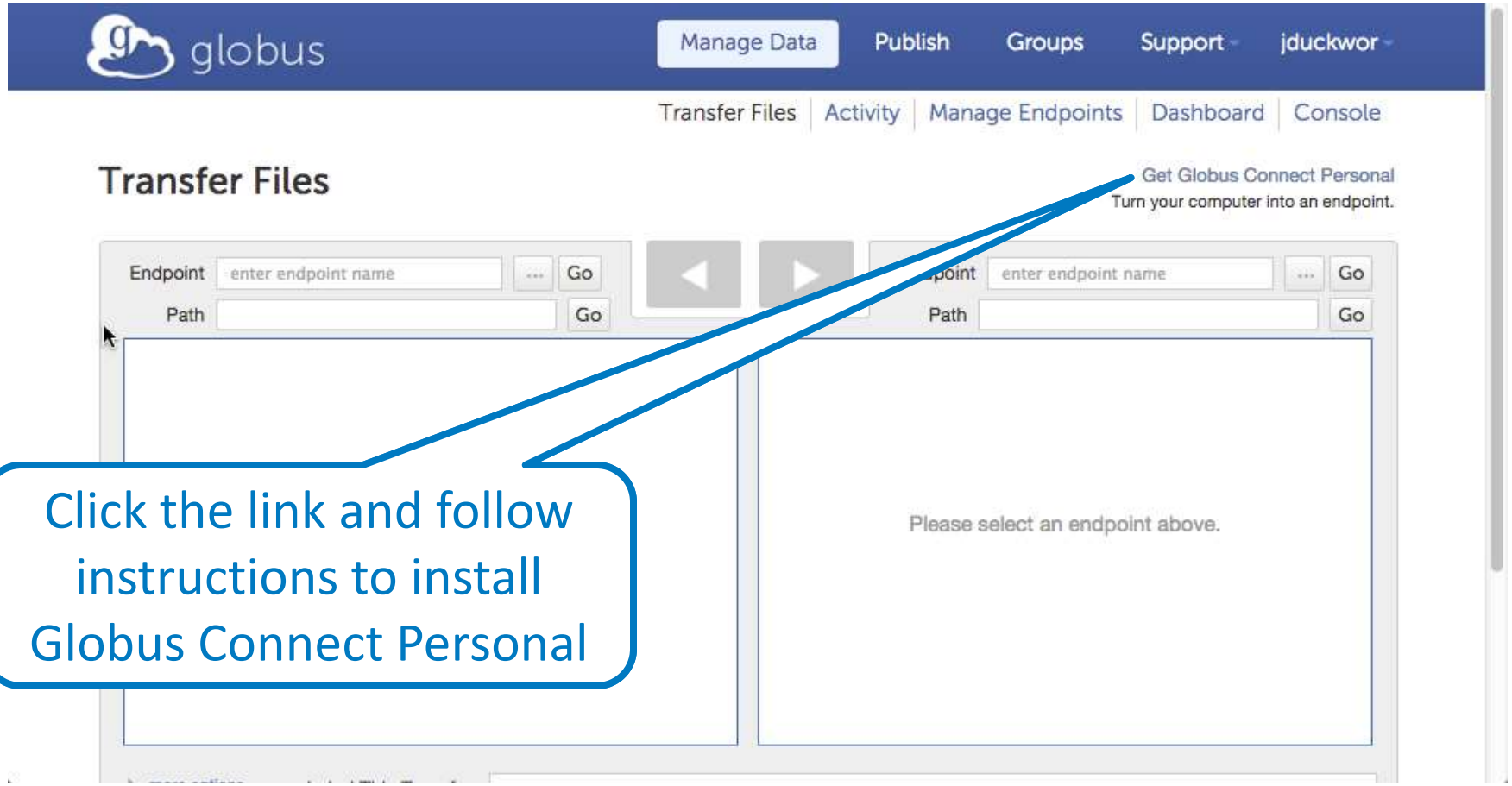

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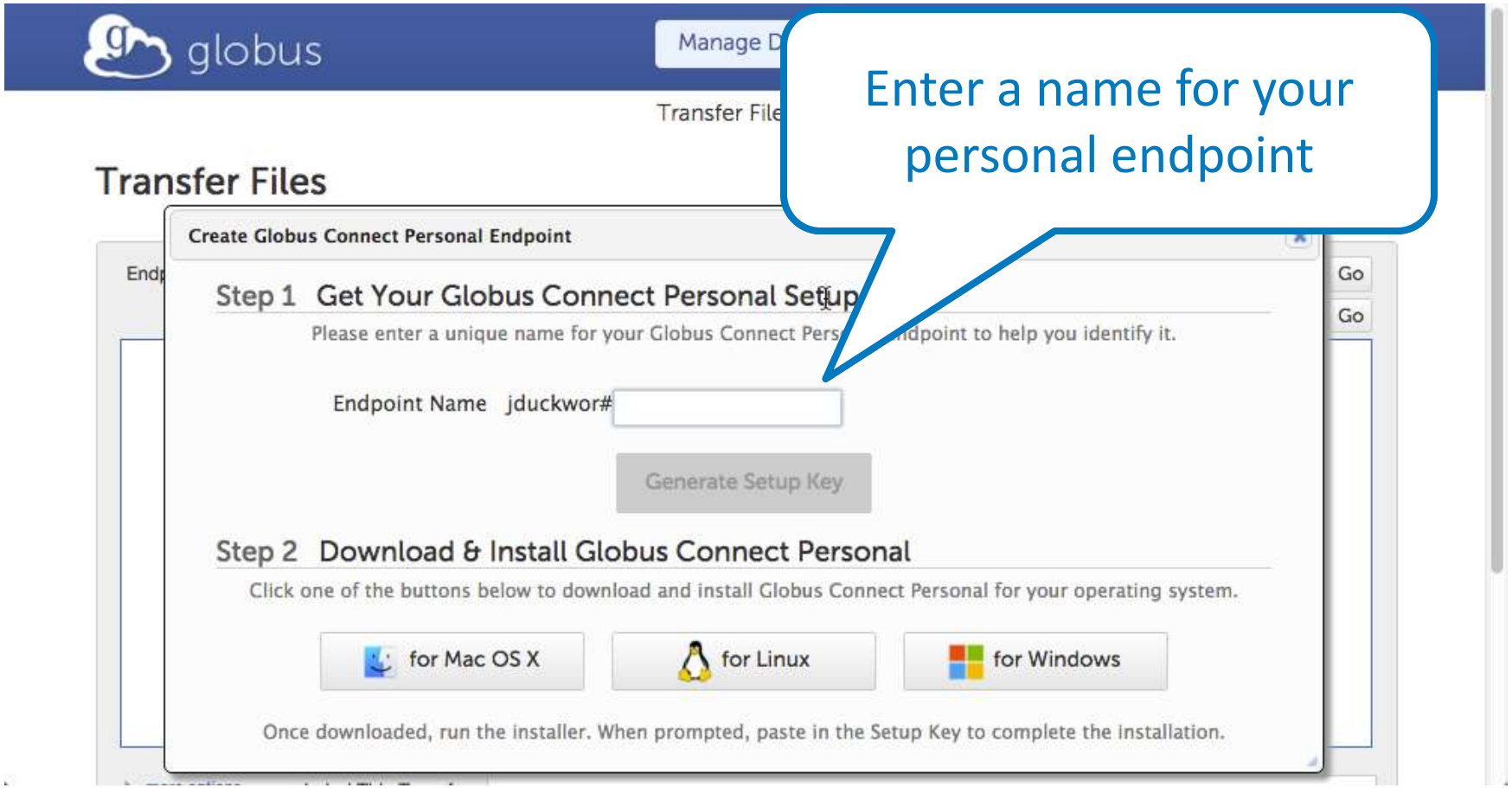

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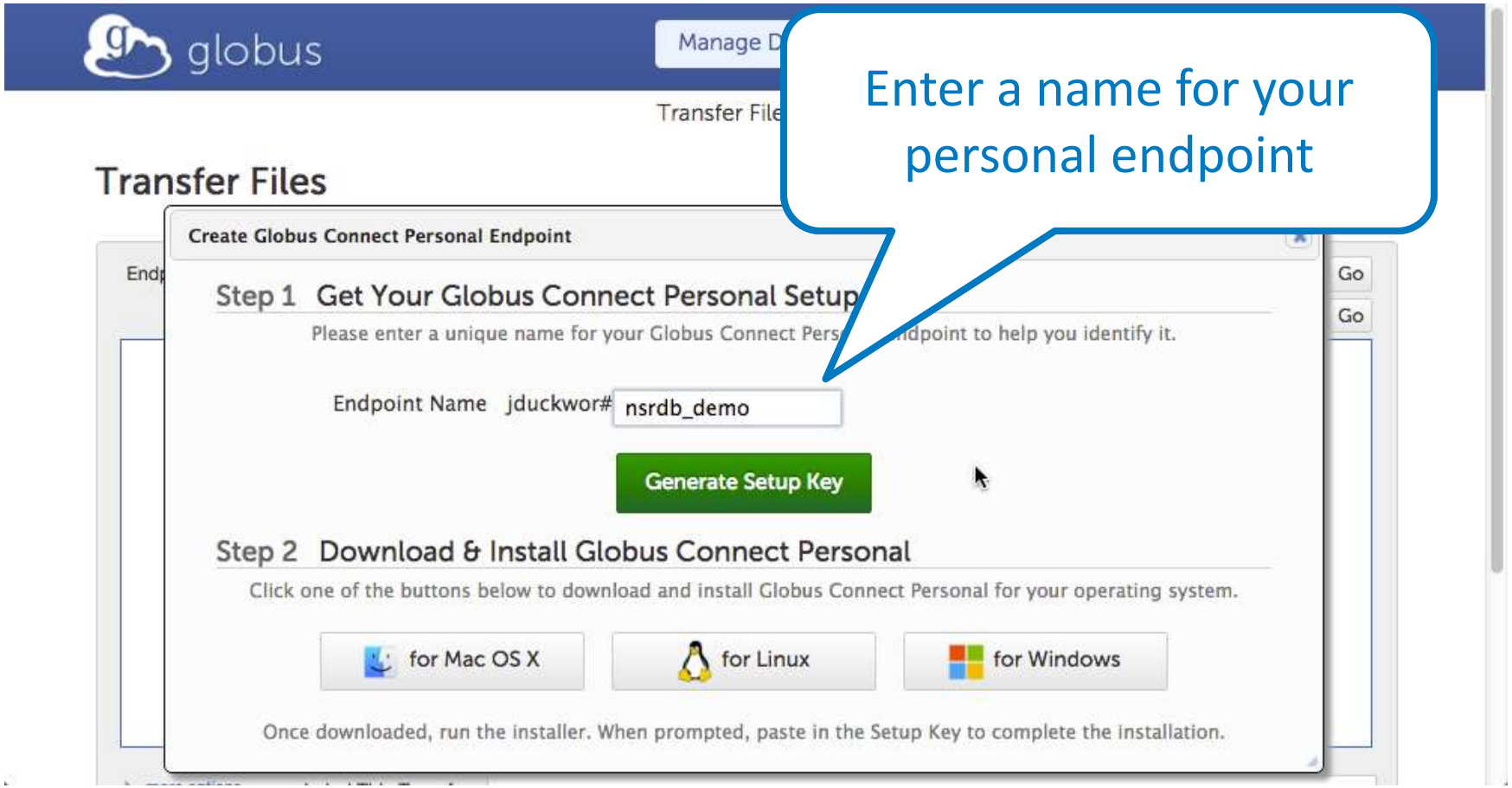

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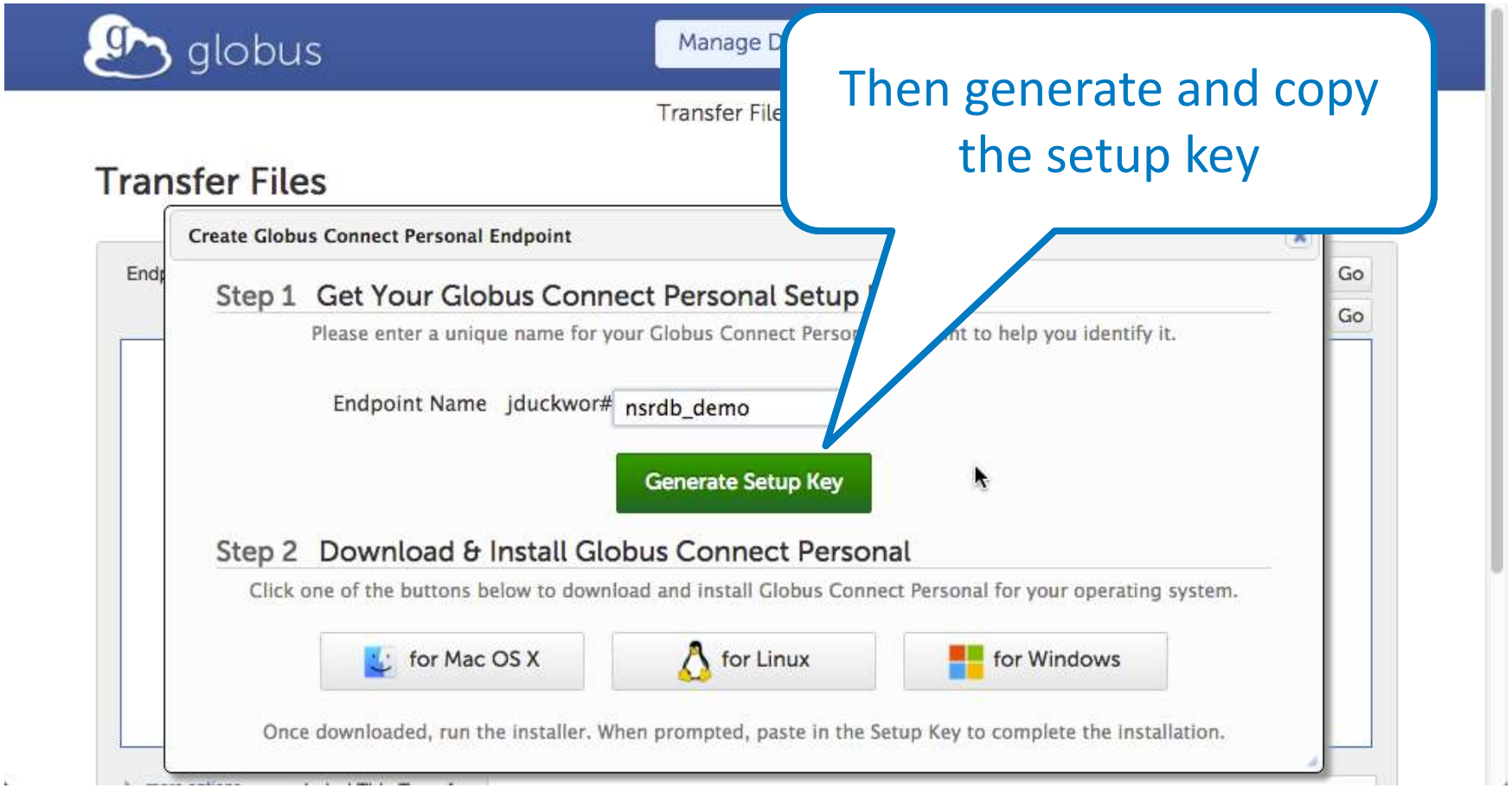

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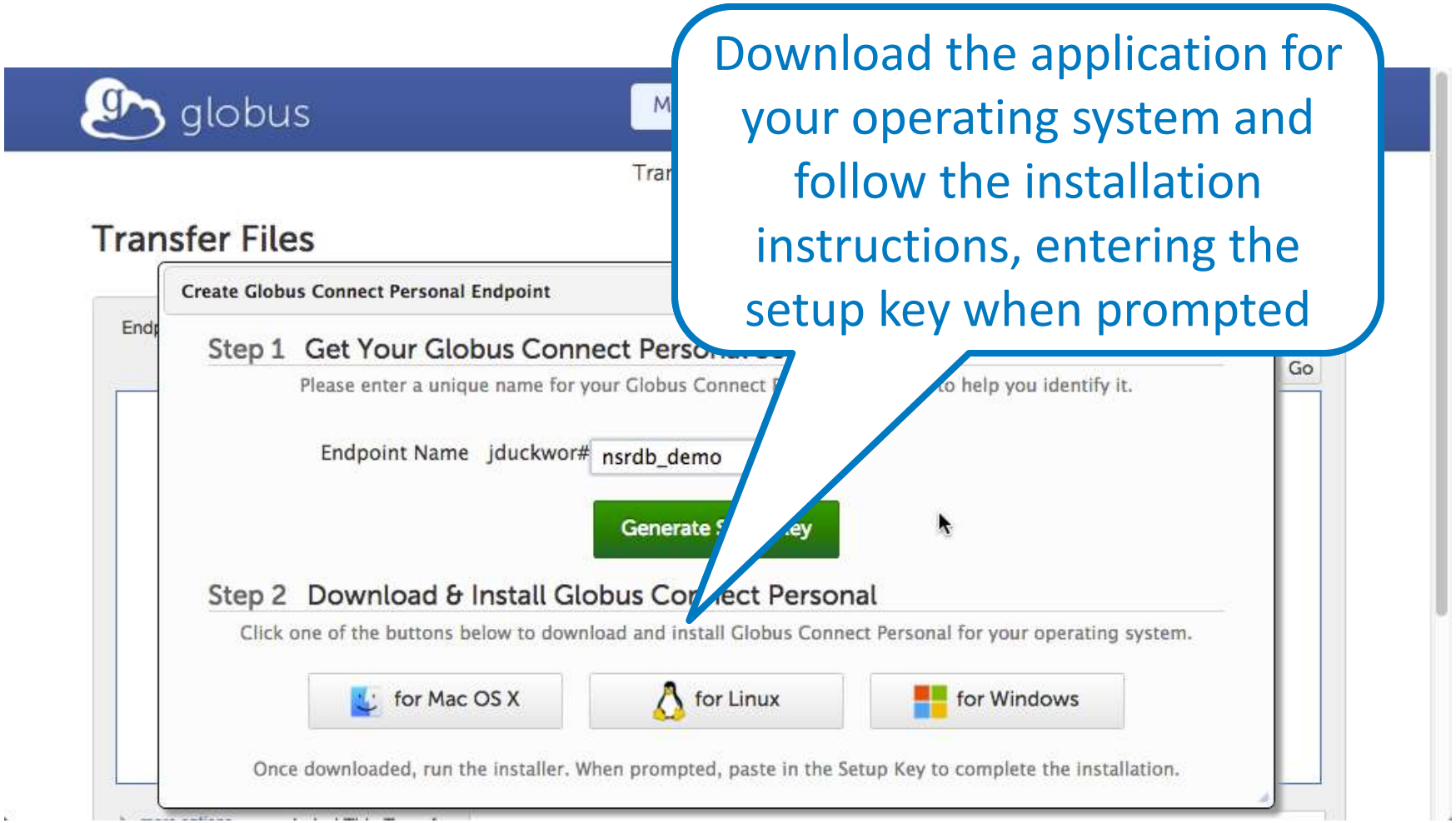
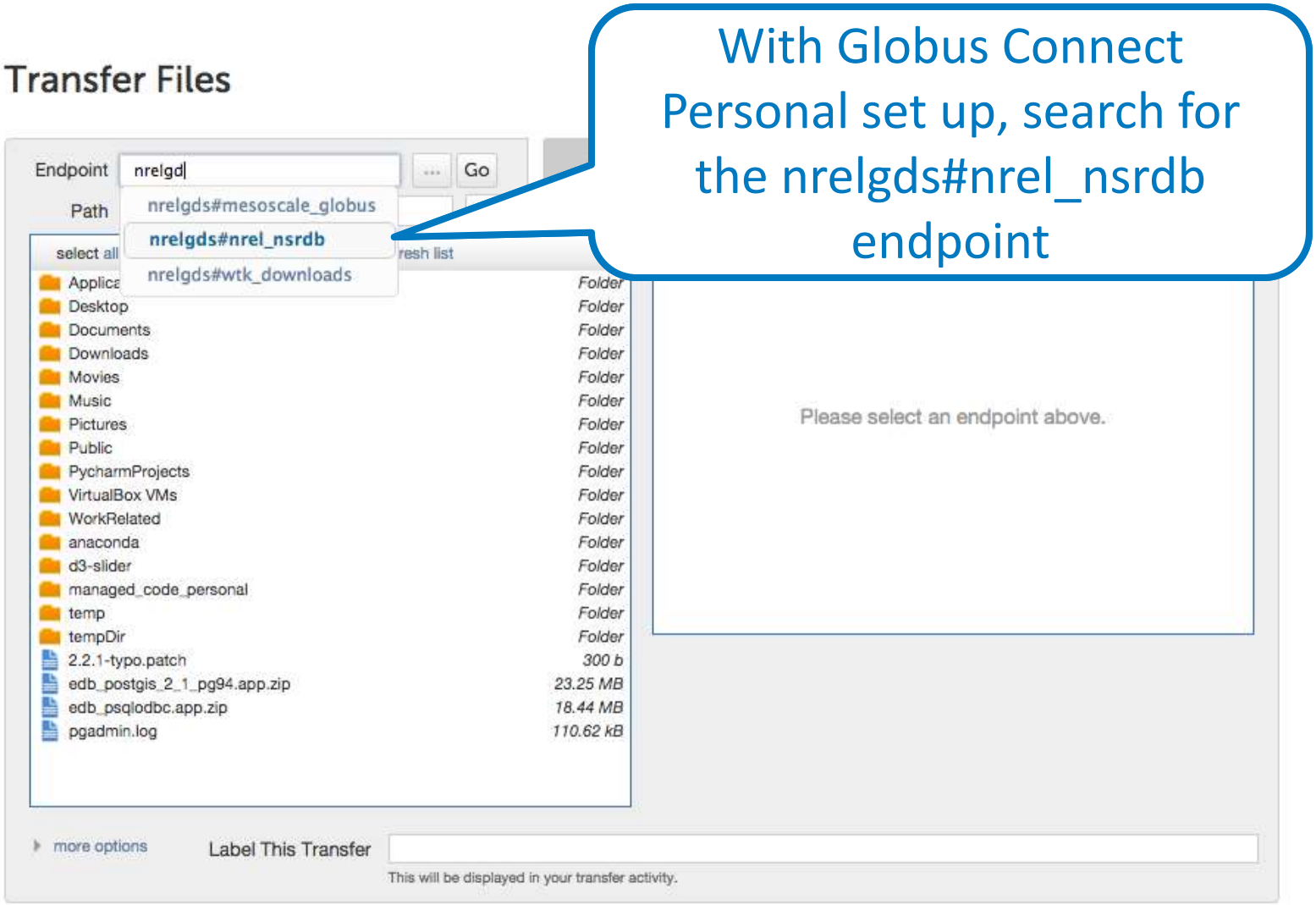


Download the application for your operating system and follow the installation instructions, entering the setup key when prompted

NSRDB Data Download



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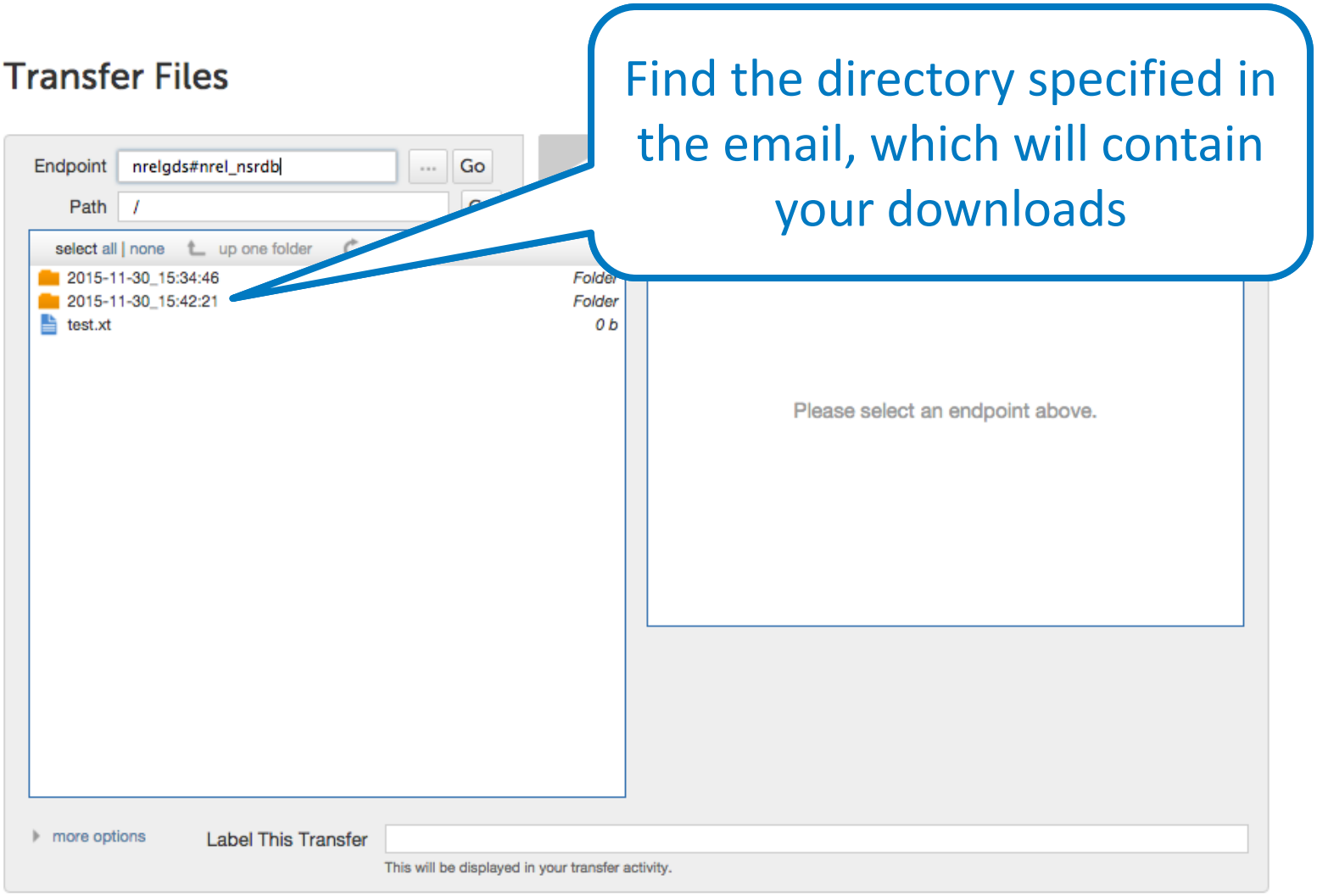

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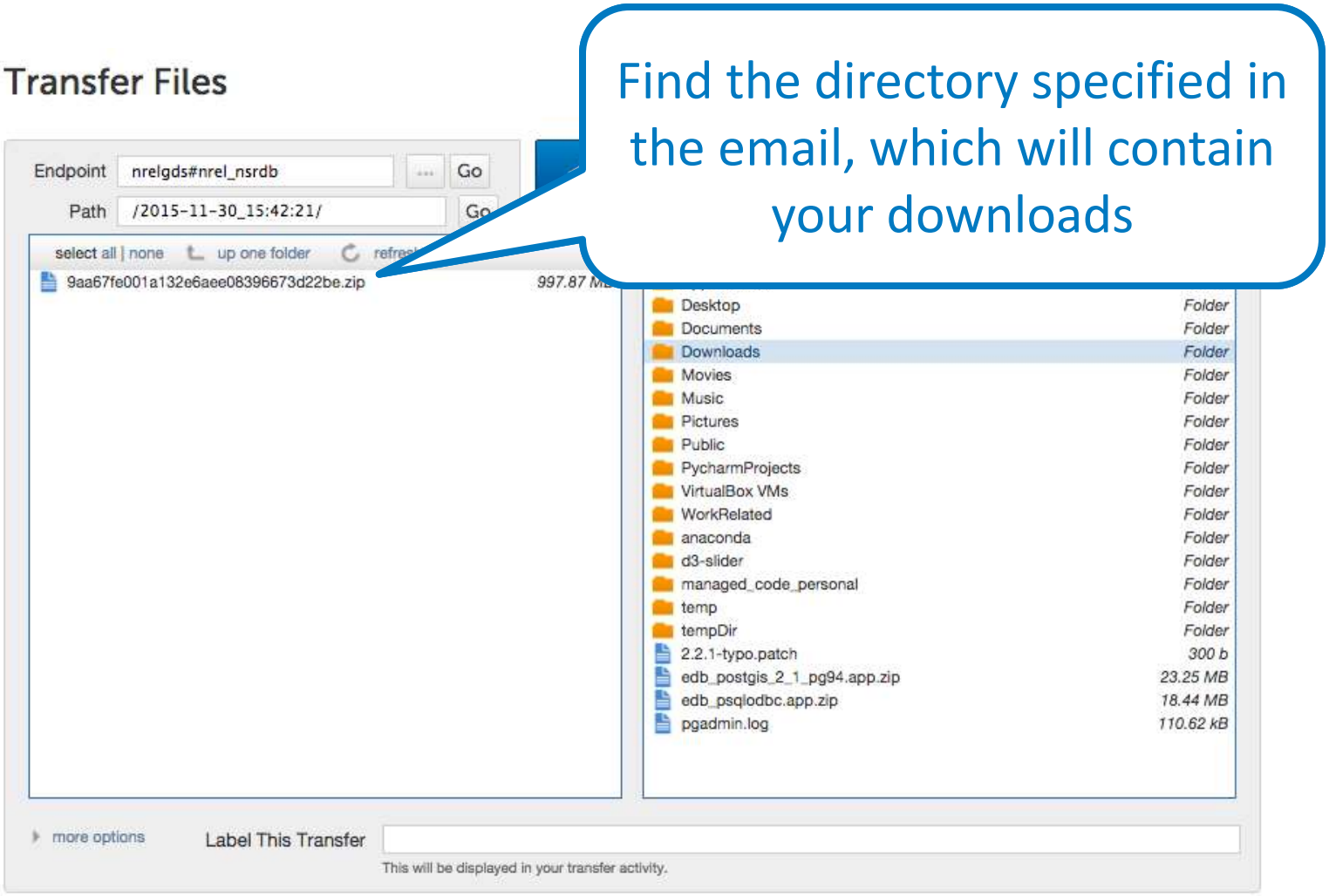

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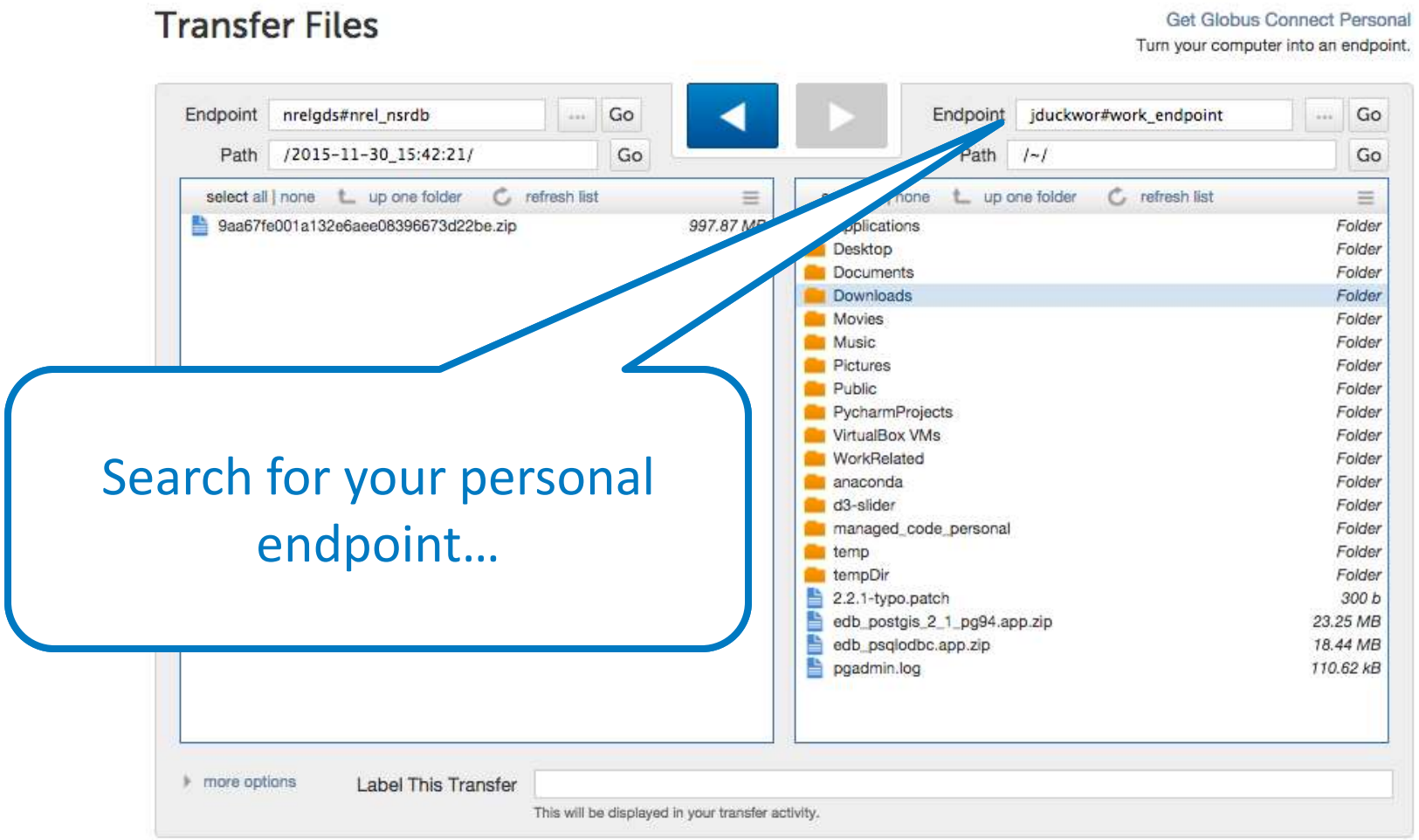

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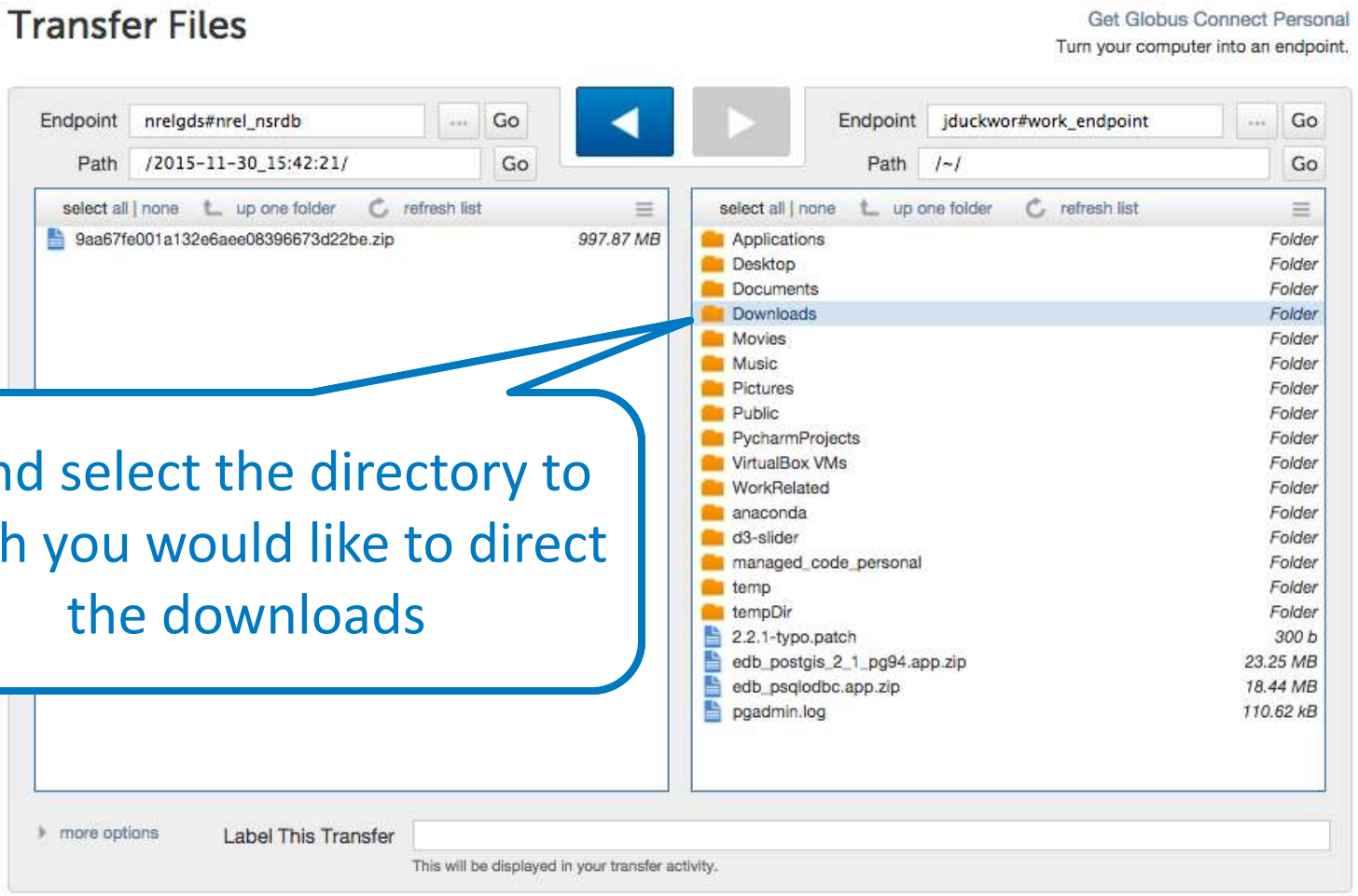

… and select the directory to which you would like to direct the downloads

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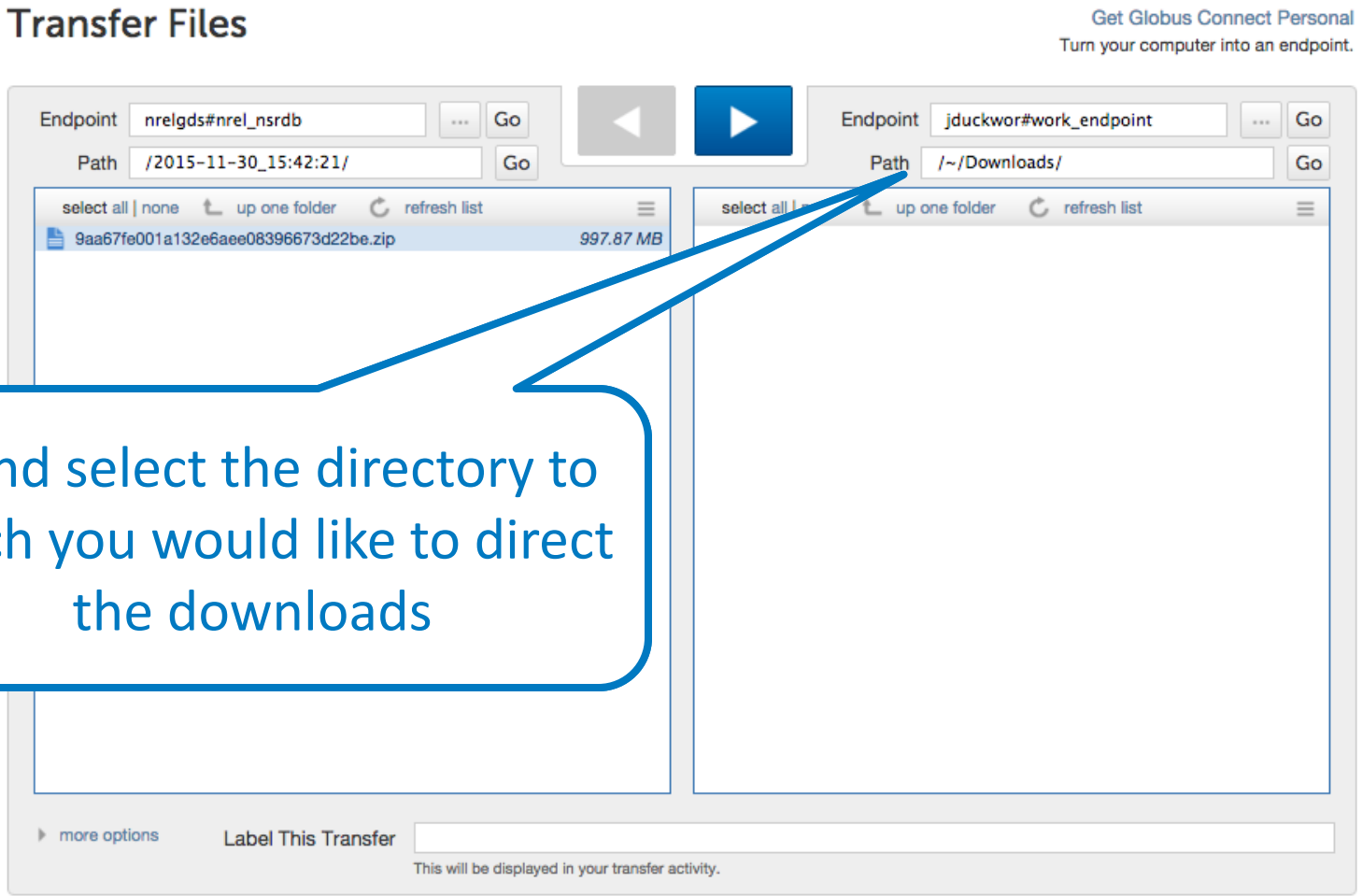

… and select the directory to which you would like to direct the downloads

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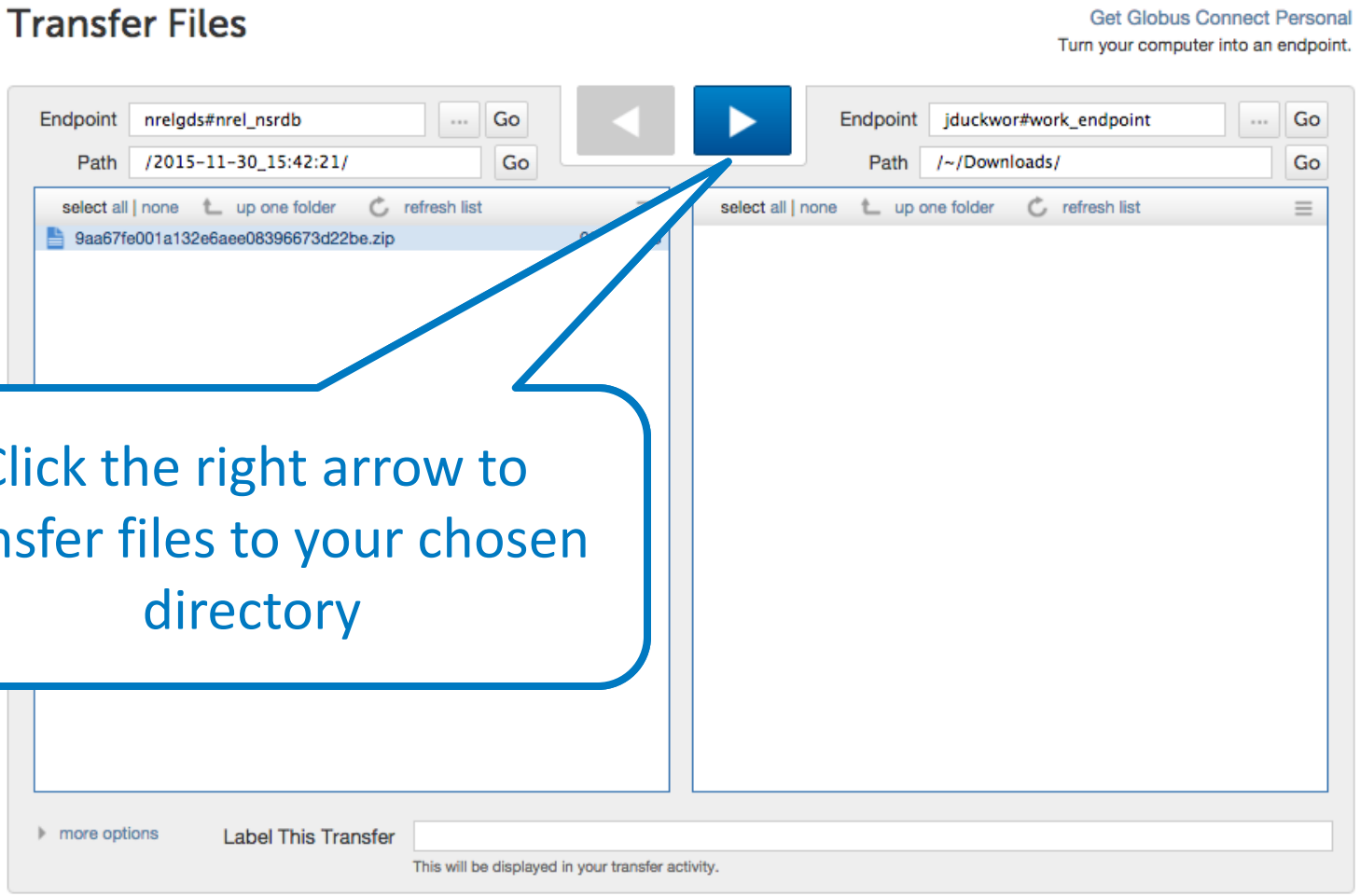
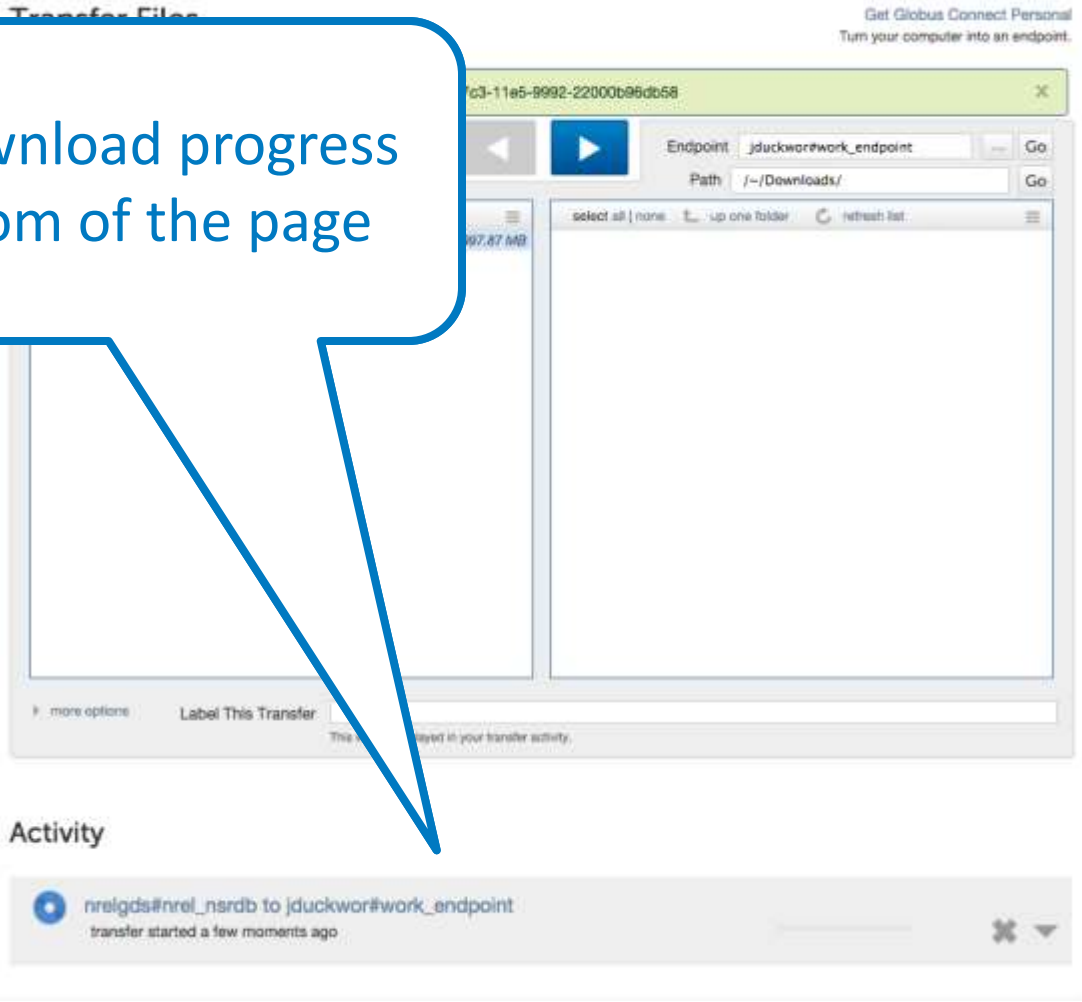


Click the right arrow to transfer files to your chosen directory

NSRDB Data Download

Monitor download progress at the bottom of the page



Data Format

Standard Time-Series Data File Format
also known as **SAM CSV**

Header

Field	Units	Recognized Names
Latitude	degrees	*latitude,lat*
Longitude	degrees	*longitude,lon,long,lng*
Time zone	hours offset from GMT	*tz,timezone,time zone*
Site elevation	meters above sea level	*el,elev,elevation,site elevation*
Year	n/a	*year*
Location ID	n/a	*id,location,location id,station,station id,wban,wban#*
City	n/a	*city*
State	n/a	*state,province,region*
Country	n/a	*country*
Source	n/a	*source,src*
Description	n/a	*description,desc*
URL	n/a	*url*
Units flag	`yes` or `no`	*hasunits,units*
Interpolate flag	`yes` or `no`	*interpmet*

Data Format

Data Columns

Field	Units	Recognized names
Year	1950-2050	*year,yr*
Month	1-12	*month,mo*
Day	1-31	*day*
Hour	0-23	*hour,hr*
Minute	0-59	*min,minute*
Global horizontal irradiance	W/m2	*gh,ghi,global,global horizontal,global horizontal irradiance*
Beam normal irradiance	W/m2	*dn,dni,beam,direct normal,direct normal irradiance*
Diffuse horizontal irradiance	W/m2	*df,dhi,diffuse,diffuse horizontal,diffuse horizontal irradiance*
Ambient dry bulb temperature	C	*tdry,dry bulb,dry bulb temp,temperature,ambient,ambient temp*
Wet bulb temperature	C	*twet,wet bulb,wet bulb temperature*
Dew point temperature	C	*tdew,dew point,dew point temperature*
Wind speed	m/s	*wspd,wind speed*
Wind direction	deg	*wdir,wind direction*
Relative humidity	%	*rh,rhum,relative humidity,humidity*
Atmospheric pressure	millibar	*pres,pressure*
Snow cover	cm	*snow,snow cover,snow depth*
Ground reflectance (albedo)	0..1	*albedo,alb*
Aerosol optical depth	0..1	*aod,aerosol,aerosol optical depth*

NSRDB API

Variable	Description	Inputs
names	Year of interest	1998-2014; tmy
interval	30 minute or hourly data	30; 60
full_name	Name user	Text
affiliation	Affiliation of user	Text
reason	Short description of purpose for downloading data	Text
Attributes	Attributes to return	dhi,dni,ghi,clearsky_dhi,clearsky_dni,clearsky_ghi,cloud_type,dew_point,surface_air_temperature_nwp,surface_pressure_background,surface_relative_humidity_nwp,solar_zenith_angle,total_precipitable_water_nwp,snow_depth,wind_direction_10m_nwp,wind_speed_10m_nwp,fill_flag

NSRDB API

http://developer.nrel.gov/api/solar/nsrdb_0512_download.csv?wkt=POINT({-104.5%2039.5)&names=1998&leap_day=false&interval=30&utc=false&full_name=YOUR_NAME&email=YOUR_EMAIL&affiliation=NREL&mailing_list=false&reason=SAM&api_key=YOUR_API&attributes=dhi,dni,wind_speed,surface_air_temperature

Sample API Call

Sample Python using Pandas

In [2]:
```
# year and location of interest
year, lon, lat = 2006, -104.5, 39.5
# Grabbing all but first 2 lines
df = pd.read_csv('http://developer.nrel.gov/api/solar/nsrdb_0512_download.csv?wkt=POINT({lon}%20{lat})&names={year}&lea
# Set the time index in the pandas dataframe
df = df.set_index(pd.date_range('1/1/{yr}'.format(yr=year), freq='30Min', periods=17520))
# off and running!
df.head()
```

Out[2]:

	Year	Month	Day	Hour	Minute	DHI	DNI	Temperature	Wind Speed
2006-01-01 00:00:00	2006	1	1	0	0	0	0	3.487848	5.069017
2006-01-01 00:30:00	2006	1	1	0	30	0	0	3.631738	4.952465
2006-01-01 01:00:00	2006	1	1	1	0	0	0	3.775598	4.835914
2006-01-01 01:30:00	2006	1	1	1	30	0	0	3.790918	4.583948
2006-01-01 02:00:00	2006	1	1	2	0	0	0	3.806238	4.331983

Data Availability

- **USA: 1998-2014**
- **Other countries: 1998-2014, with 2005-2012 available publicly**
  - List of Countries: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Canada, Cape Verde, Cayman Island, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Kiribati, Mexico, Montserrat, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Barthélemy, Saint Lucia, Sint Maarten, St Vincent and the Grenadines, St-Martin, St. Kitts and Nevis, St. Pierre and Miquelon, Suriname, Trinidad and Tobago, Turks and Caicos Islands, U.S. Minor Outlying Islands, U.S. Virgin Islands, and Venezuela
  - To obtain the full 1998-2014 dataset, please contact nsrdb@nrel.gov

Future Plan

- **Summary statistics layers**
- **Biannual updates**
- **Spectral data**
- **Plane-of-array irradiance**
- **Algorithm improvements**
- **Fix some outstanding issues**
  - Relative humidity

Questions?

Main Website: nsrdb.nrel.gov

Publications: nsrdb.nrel.gov/publications

Access Data: nsrdb.nrel.gov/nsrdb-viewer